The Impact of Metrorail on Trip Making by Nearby Residents: The Van Ness Case Study

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ABSTRACT

In a before-and-after study of the impacts of extending Metrorail service into a dense residential community of 30,000 persons along upper Connecticut Avenue in Washington, D.C., it was found that there was substantial diversion of nonwork automobile trips to transit by those who are not in the work force and have a car in the household, a diversion of work trips to transit for both workers with a car in the household and those with no car, and no significant increase in the total amount of daily nonwork trip making, because transit increases were matched by reductions in automobile trips.

Much of the analysis of transit use has focused on the commuting trip. The Metrorail before-and-after study concentrated initially on determining the impact of the Metrorail system on commuting to downtown Washington and adjacent employment centers in Arlington County, Virginia. The extension of Metrorail's Red Line from a terminus at DuPont Circle, on the edge of downtown, into residential neighborhoods as far as 2 miles north on Connecticut Avenue provided a unique opportunity to study the effects of nearby rail service on travel from a residential neighborhood within walking distance, especially for nonwork trips.

STUDY AREA

The study area is shown in Figure 1. It is bounded generally by Rock Creek Park on the east and south, Massachusetts and Wisconsin avenues on the west, and Ellicott Street and Nebraska Avenue on the north. It includes the residential neighborhoods of Woodley Park, Cleveland Park, Tenleytown, North Cleveland Park, and Forest Hills. As shown in Table 1, it is primarily an area of multifamily housing, with many large older apartment complexes along Connecticut and Wisconsin. The automobile ownership is relatively low; a high percentage of households are without cars and few have more than one. The District of Columbia is the dominant work location; a relatively high percentage of commuters use transit. Between 1970 and 1980, there was a slight increase in the area's population, to 29,136, which is unusual for a highly urban community.

CHANGES IN TRANSPORTATION SERVICE

The principal radial arterial street in the corridor is Connecticut Avenue. The study area extended about 1 mile to the west to Wisconsin Avenue, although the majority of the population is relatively close to Connecticut Avenue. The three Metrorail stations that opened in December 1981 provided direct service to the previous terminal station 2 miles away, DuPont Circle. More than 90 percent of the survey respondents reported that they were located within walking distance of one of these new rail stations. Headways were the same as previous service on the Red Line--6 min during peak periods and 10 min during midday.

The opening of Metrorail service was accompanied by a major rerouting of the bus system to feed the rail stations and eliminate competing service. In the spring following the opening of the rail system, the number of local buses on Connecticut Avenue at Klingle Street, in the middle of the corridor, was reduced from an average of 21 to 14 buses per hour in the peak direction during the three morning peak hours. The reduction in express bus service (which did not stop in the corridor) was even more dramatic--from 22 to 8 per hour. Midday bus service had also been quite high before the extension of rail

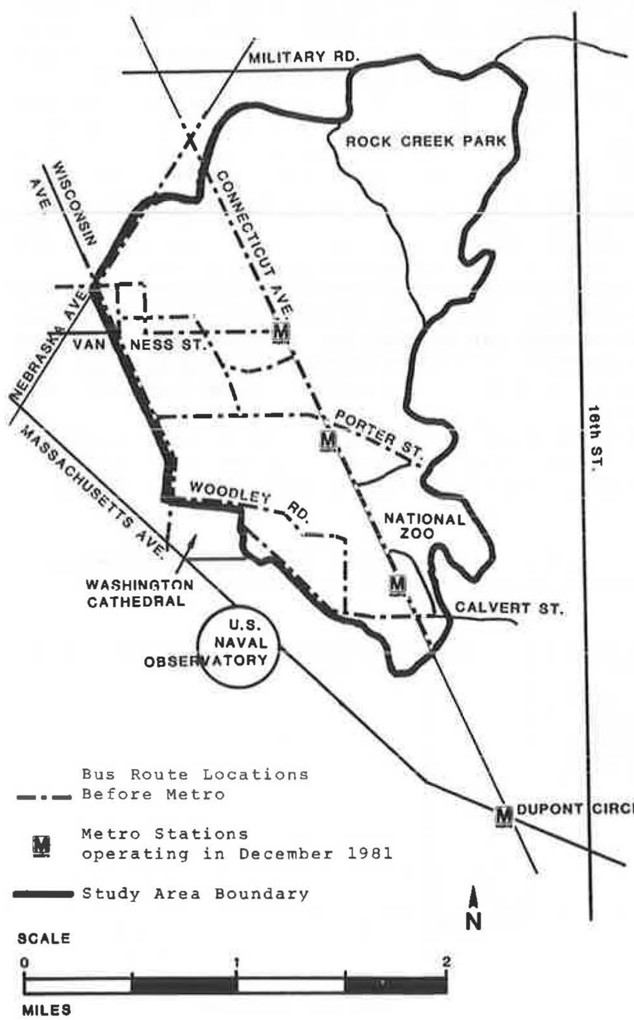

FIGURE 1 Map of study area.

TABLE 1 Characteristics of Van Ness Community, 1980

Parameter	No.	Percent
Housing		
Single family detached	2,308	15
Townhouse	1,132	8
Apartments (units)		
2-4	192	1
5+	11,350	76
Total	14,982	
Population		
1970	26,344	-
1980	29,136	-
Automobile ownership		
No car	-	32
One car	-	52
Multicar	-	15
Means of travel to work		
Drive alone	5,043	35
Carpool	1,970	13
Public transportation	5,779	39
Walk	1,035	7
Other	834	6
Total	14,661	
Family characteristics		
Live alone	-	58
Family	-	34
Other	-	8

Note: Data are from 1980 census.

service--11 buses per hour in each direction between 9:30 a.m. and 3:30 p.m.--an average of 1 bus almost every 5 min.

Bus ridership was high in this corridor before Metrorail service was extended. Counts of transit riders entering the regional employment core made by the Council of Governments (COG) found that Connecticut Avenue buses carried the second highest volume of any route during the morning peak except the Shirley Highway bus lanes. Moreover, the average occupancy of Connecticut Avenue buses immediately before the extension of the Metrorail system was the highest of any route entering the downtown. An average of 48 passengers per bus was carried for the period between 6:30 a.m. and 9:30 a.m. on both local and express buses.

Travel time comparisons before and after the Metrorail service extension are complicated by their variance according to the orientation of the trip. However, morning peak period running times from Van Ness to DuPont Circle averaged 21 min by bus before the extension of Metrorail as opposed to a station-to-station time of 6 min by rail, a 15-min saving. This saving may be reduced by longer walking times to destinations on Connecticut Avenue between Metrorail stations and time needed to get through the rail station.

STUDY DESIGN

The initial focus of this study was on nonwork travel, as described earlier. The data are part of a set of related surveys intended to measure several components of travel changes in the corridor. The study issues identified originally were as follows:

1. How does nonwork trip generation change?
2. How does nonwork transit use among non-car-owning households change?
3. How does rail transit affect nonwork transit trips and automobile use among persons in households with cars?

In order to analyze nonwork travel changes of community residents, before-and-after surveys were conducted by telephone.

A question about commuter trips was added during the questionnaire design when it was determined that proper reporting of nonwork trips required collecting all daily trips made by the respondent. This would make it possible to probe for midday trips by workers. The initial survey was conducted during the fall of 1981. The consultant, John R. Hamburg and Associates, used a systematic sample to select names from a reverse telephone directory. One individual was interviewed from each responding household. The interviews after service extension were conducted by the COG staff in the spring of 1982 following the Metrorail extension on December 5, 1981. A computer-assisted telephone interview technique was developed, which made it possible to obtain data on prior travel mode of residents reporting the use of Metrorail from one of the three new stations. The same individuals responding in the survey made before the service extension were used as the sample frame for the survey after the extension. This panel of the same individuals surveyed twice yielded a paired sample of 178 persons from households without cars and 434 persons from households with one or more cars. The further breakdown by worker status is as follows for the survey after service extension:

	Automobile Availability	
Worker Status	None	One or More
Employed	84	310
Not employed	94	124
	178	434

Because of the special interest in analyzing the impact of Metrorail on different market segments, most of the following analysis is reported separately for each cell.

COMMUTING CHANGES

It was not expected that the Metrorail extension would result in a significant change in the number of work trips per commuter, which are felt to be insensitive to transportation supply. In fact, as shown in the following tabulation, there was a slight, statistically insignificant decline in the number of home-based work trips per worker:

	Daily Home-Based Work Trips per Worker	
Car Ownership of Household	Before Metrorail Extension	After Metrorail Extension
One or more	1.56	1.49
None	1.54	1.43
All households	1.55	1.48

It is likely that there was a higher level of vacation days taken in the spring, when the second survey was conducted. Changes in relative transit use are described separately, depending on whether an automobile was available to the household.

Households with Cars

Use of transit by commuters in car-owning households, relatively high at 38 percent before the extension of Metrorail, increased by 9 percentage points after the opening of the new rail stations, as shown in Table 2. This increase was matched by an equivalent decline in the percentage of residents commuting by automobile. Although these workers report at least one vehicle in the household, there

TABLE 2 Means of Travel for Commuting by Van Ness Corridor Workers with Car in Household

	Percent of Commuters			
Means of Travel	Before Metrorail Extension	After Metrorail Extension	Change (%)	Percent Change
Transit	38.5	47.7	+9.2	+24
Automobile	53.2	43.6	-9.6	-18
Taxi	1.3	1.3	-	-
Other	7.0	7.4	+0.4	+0.5
Total			-	-4

may be commuters in one-car households who are dependent on transit because another person in the household needs the car, either for commuting or other purposes.

Following the introduction of rail transit to the corridor, transit use increased and automobile use declined, so transit became the dominant commuting mode. When considered as a percentage of the number of home-based work trips from car-owning households before the Metrorail extension, the 9+ percent shift in the market share between transit and automobile amounts to a 24 percent increase in the number of transit commuters and an 18 percent reduction in the number of automobile commuters. Some of this change occurred among those who may not have had regular access to a commuting vehicle. However, it appears that most of the shifts in commuting occurred among workers with an automobile available, for whom Metrorail provided a better alternative. No significant changes were observed in commuting by taxi or other (mostly walking) modes.

Households Without Cars

Persons from households without automobiles can truly be described as transit dependents. Although in general such households cannot afford an automobile, the income data suggest that this is not true of most of the survey area residents. Many of the 32 percent of households who do not have cars have apparently made that decision because of the excellent transit service combined with neighborhood parking limitations. In addition, some older residents may be unable to drive because of physical limitations.

An overwhelming share of workers from households without cars (73 percent) commuted by transit before the opening of the new Metrorail stations. As shown in Table 3, the transit share of commuting increased by more than 10 percentage points even within this transit-dependent category. Most of the increased transit use was diverted from the automobile category, which declined by 7 percentage points. Although these commuters do not have access to a car at home, it is possible for them to ride with others, either as a favor or by sharing costs. However, because these commuters cannot reciprocate by sharing driving, such arrangements can be difficult. A decline of more than 2 percent was reported in the share of other types of travel, most of which is walking. There was also a decline of 1 percent in the share of commuters without cars who use taxis to get to work. Although such small changes were not statistically significant for this size of survey, the data suggest that these modes are used to a disproportionate amount by persons without cars because they are not satisfied with the existing transit service.

The introduction of the Metrorail extension to the Van Ness neighborhood resulted in an increase in the transit share among carless commuters comparable with that of workers with a car in the household. Because transit commuting among transit-dependent workers was already so high before the opening of the new stations, the number of transit trips in this category increased by only 14 percent. This increase was accompanied by a reduction of 71 percent in commuting as automobile passengers as well as smaller reductions in taxi travel and walk trips. Although the increase in transit use by commuters without cars may not have removed any automobiles from the streets, it has appeared to offer such individuals a higher level of mobility.

NONWORK TRAVEL

The potential effects of Metrorail on nonwork travel are twofold:

1. Increased transit use for existing trips and
2. New trips induced by the service improvement (unlike work-trip rates, which are assumed to be inelastic to transportation service).

Because the opening of the new Metrorail stations affected transit accessibility primarily at the home end, the analysis of nonwork travel impacts was conducted separately for home-based and non-home-based trips.

Home-Based Nonwork Trips

Most nonwork travel consists of round trips from home to a destination and back home. A non-home-based trip occurs as one leg of a tour from home to more than one destination before returning home. This analysis of home-based nonwork trips includes all of the round trips as well as the home-based ends of the tours.

The average number of daily home-based nonwork trips before and after the Metrorail extension is shown in Table 4, classified by labor force status and automobile availability. The trip rates before

TABLE 3 Means of Travel for Commuting by Van Ness Corridor Workers Without Car in Household

	Percent of Commuters			
Means of Travel	Before Metrorail Extension	After Metrorail Extension	Change (%)	Percent Change
Transit	73.4	83.9	+10.5	+14
Automobile	9.7	2.8	-6.9	-71
Taxi	3.9	2.8	-1.1	-28
Other	13.0	10.5	-2.5	-19
Total			-	-6

TABLE 4 Daily Home-Based Nonwork Trip Rates by Residents of Van Ness Corridor

	Trips per Person		
Category	Before Metrorail Extension	After Metrorail Extension	Change
Workers			
Households with cars	1.06	1.09	+0.03
Households without cars	0.59	0.67	+0.08
Nonworkers			
Households with cars	1.94	1.94	-
Households without cars	1.18	1.20	+0.02

and after the service extension are generally close and none of the differences are statistically significant. The largest difference occurred in the category of workers without cars, where home-based nonwork trips increased by about one-tenth of a trip per day (14 percent). It appears that the service extension has not resulted in a substantial increase in total nonwork travel from homes within walking distance of the new stations.

A comparison of trip rates by type of traveler showed that persons who are not employed made significantly more home-based nonwork trips than did workers and that those with at least one car in the household made more nonwork trips than those without a car. The highest amount of daily home-based nonwork travel, almost two trips per day, occurred among those who had access to a car and were not working. The lowest rate occurred among the employed without cars, who made an average of only about two-thirds of a home-based nonwork trip per day. Combining the home-based nonwork trips from Table 4 with the number of home-based work trips reported earlier results in a daily total for home-based trips by workers that is higher than that for persons not employed. The highest trip rate for home-based trips was for workers with cars, who averaged about 2.5 trips per day. Workers in households without cars averaged slightly more than 2 home-based trips per day, whereas nonworkers in car-owning households averaged slightly less than 2 daily trips. The lowest daily trip rate occurred among nonworkers without cars, who made an average of slightly more than 1 home-based trip per day.

The number of total daily home-based nonwork trips made on transit by corridor residents is shown in Table 5 by labor force status and automobile availability. Transit use was found to have increased for those in households with cars and to have decreased for those in households without cars.

TABLE 5 Daily Home-Based Nonwork Transit Trip Rates by Residents of Van Ness Corridor

	Trips per Person		
Category	Before Metrorail Extension	After Metrorail Extension	Change
Workers			
Households with cars	0.05	0.10	+0.05
Households without cars	0.34	0.37	-0.03
Nonworkers			
Households with cars	0.15	0.34	+0.19[a]
Households without cars	0.91	0.87	-0.04

[a]Statistically significant at 95 percent level of confidence.

However, the only category with a statistically significant change was that of nonworkers in households with cars, who more than doubled their daily transit trip making with an increase of 0.19 trip per day. This was also the only category with a reduction in the number of daily automobile trips for home-based nonwork purposes, which declined by 26 percentage points, a 15 percent reduction. This finding suggests that the opening of new Metrorail stations in the neighborhood has made it possible for persons not in the work force to divert nonwork automobile trips to transit. Changes in home-based nonwork travel by mode before and after the service extension are shown in Figure 2 for workers and in Figure 3 for nonworkers. The latter do not have the time limitations of workers, which preclude additional nonwork transit travel. Rail trips, although

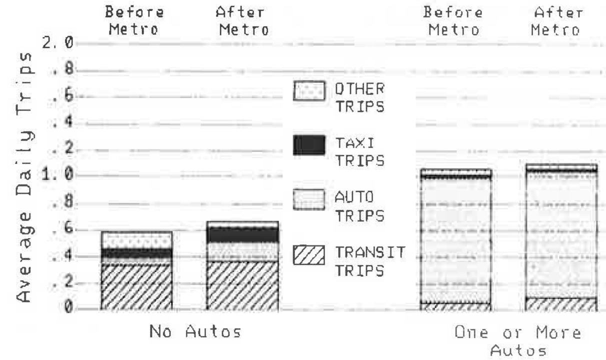

FIGURE 2 Home-based nonwork trips by workers.

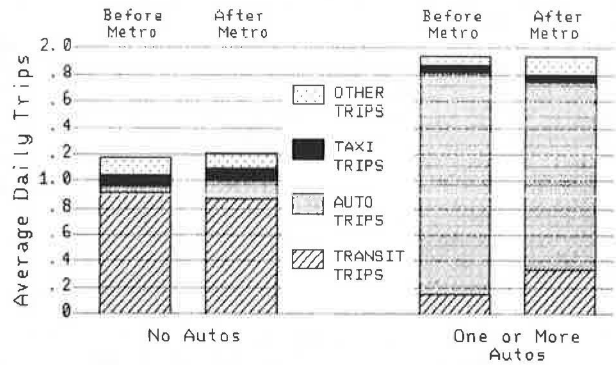

FIGURE 3 Home-based nonwork trips by nonworkers.

possibly faster than by the existing bus, are generally slower than a comparable trip by automobile, especially during off-peak hours. Because persons from households without cars are already frequent transit users, it is difficult to increase their transit trip making for home-based nonwork trips. Finally, a much sharper difference is found in the use of transit for home-based nonwork purposes between those in car-owning households and those without cars compared with transit use for commuting by those two types of households.

Non-Home-Based Trips

The opening of three new Metrorail stations in the study corridor can be shown to have increased transit service for home-based trips by residents. Its impact on non-home-based trips is not obvious. Downtown workers and others traveling to the central business district (CBD) had the advantage of Metrorail service for their intra-CBD trips even before the survey. The opening of the new stations therefore would serve only those non-home-based trips made along the Connecticut Avenue corridor. Comparisons of daily non-home-based trip rates for an average resident of the corridor are shown in Table 6 before and after the Metrorail service extension. Although the change in trip rates for non-home-based trips by workers was small, there was a large increase for nonworkers, both with and without cars. On further analysis of the data by mode, it is found that the increases are primarily in automobile trips for those with cars and in transit trips for those without cars. The increase in automobile travel by nonworkers with access to an automobile suggests that the increase is not related to the change in Metrorail service. It is more likely to be a sea-

TABLE 6 Daily Non-Home-Based Transit Trip Rates by Residents of Van Ness Corridor

	Trips per Person		
Category	Before Metrorail Extension	After Metrorail Extension	Change
Workers			
Households with cars	0.85	0.88	+0.03
Households without cars	0.57	0.47	-0.10
Nonworkers			
Households with cars	0.12	0.33	+0.21
Households without cars	0.13	0.34	+0.21

sonal factor, because both categories of nonworkers increased their daily travel by the same amount, even though one used primarily transit and one primarily automobile.

Changes in the transit share of non-home-based trips are shown in Table 7. The use of transit for these trips is greater than it is for home-based nonwork trips in each category except that of nonworkers with cars. This is probably because of the primarily downtown orientation of both workers and nonworkers. A non-home-based trip is therefore likely to occur within the downtown region, where Metrorail provides excellent service. Moreover, because more workers reported commuting by transit, they are more likely to use transit for midday trips. Although increases were observed in the transit share of non-home-based trips by workers, the small sample sizes and low trip rates make these changes statistically insignificant.

TABLE 7 Relative Transit Use for Non-Home-Based Trips by Residents of Van Ness Corridor

	Percent of Trips by Transit		
Category	Before Metrorail Extension	After Metrorail Extension	Change (%)
Workers			
Households with cars	21	24	+3
Households without cars	53	66	+13
Nonworkers			
Households with cars	0	6	+6
Households without cars	100	76	-24

It appears that there is no statistically significant effect of the extension of Metrorail on non-home-based trips made by corridor residents, probably because most trips were located outside the corridor.

CONCLUSIONS

In the analysis of changes in travel behavior before and after the extension of Metrorail's Red Line into the Van Ness Community the following results were found:

1. There was an almost equal increase of more than 9 percent in the transit share of home-based work trips for workers without automobiles as well as for those from car-owning households,
2. Transit use increased and automobile travel was reduced for home-based nonwork trips by those who have at least one car in the household, and
3. There was no significant change in the daily trip rates for either work or nonwork trips.

The increase in the transit share of commuting trips was not anticipated, because the mode split for home-based work trips was already so high before the rail extension. However, because of that high demand, the loading factors on buses were very high, frequently preventing a passenger from boarding the first bus. The additional capacity provided by Metrorail allowed an almost equal increase of 10 percentage points in transit use for both workers from car-owning households and those without an automobile. This is similar to an earlier conclusion in this study that transit use to the regional core increased by similar percentages for each income group, even though the base levels were much lower for high-income commuters.

The most significant relative changes in transit use by corridor residents occurred in home-based nonwork trips. Relative transit use more than doubled among those who were not employed and had at least one car in the household; there was a comparable reduction in automobile travel. Such individuals do not have the same time constraints as workers, whose nonwork travel must be fit into a schedule that is dominated by working and commuting. In this particular case, the use of an automobile in the city can be difficult during the day because of the problems with parking. It therefore appears that such individuals are willing to replace certain nonwork automobile trips with transit. Overall, they do not appear to be traveling more.

The finding of no significant change in daily travel by those without access to a car is contrary to theories about the value of transit speed for transit-dependent individuals. It has been suggested that greater transit speeds will induce more total travel for such travelers. However, in this case, the level of bus service on the main arterials serving the corridor, Connecticut and Wisconsin avenues, was quite high before the Metrorail extension. Between 9:30 a.m. and 3:30 p.m., there were 13 buses per hour scheduled in each direction on Connecticut Avenue, an average headway of less than 5 min. Because congestion during midday is relatively light, midday transit accessibility by bus was quite good before the rail extension. Moreover, walking distance to the nearest bus stop was generally much less than that to rail stops. Therefore, for many nonwork trips, Metrorail may not have provided a better alternative for transit dependents. The increase in transit use by nonworkers with a car in the household represents a choice between automobile and transit. Apparently these individuals relate the dependability of rail transit to that of the automobile. They know that they can count on Metrorail to return them from a destination without the uncertainty and route complexity of the bus system. In addition, they may be making longer trips, for which Metrorail provides a true time saving over the bus.

In summary, this analysis of travel patterns by residents of a high-density residential neighborhood close to downtown has found substantial gains in transit use, both for work and nonwork trips. For commuters the rail system has provided needed capacity over and above the prior bus system. For nonworkers used to the convenience of driving around town, Metrorail provides an alternative that is perceived to be much better than the bus. For transit dependents, however, the frequency of the bus service combined with their understanding of routes and schedules allows a level of mobility for nonwork trips that apparently has not been significantly improved by rail transit.

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The opinions presented in this paper are those of the Council of Governments Metrorail before-and-after study staff.

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A Radio-Frequency Deicing System for Third Rails

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ABSTRACT

A radio-frequency (RF) deicing system for third rails has been proposed. It consists of an RF generator, transmission lines, a work coil, and a mechanical scraper, all mounted on a train. The system definition of such a setup is presented. Several coil configurations are studied. Experimental setups for static calorimeter tests, dynamic temperature rise tests, and deicing tests are described, and results are reported. With 50-kW 185-kHz RF generator power, successful deicing was accomplished up to a speed of 43.5 km/hr at an ambient temperature of -2.2°C using a ferrite-core coil. Finally, possible future improvements to the system are discussed.

During a winter storm, snow, ice, sleet, high winds, and low temperatures often cause rail transit systems to experience a variety of equipment and operational problems. One such problem is the icing of the third rail (the rail that supplies power to trains). This causes the power collector to lose electrical contact, which results in a disabled car or creates excessive arcing. A layer of ice forms and adheres to the third rail when there is precipitation near the freezing temperature of water (0°C). Sleet storms cause the worst icing problems, but snow on the third rail that has melted in the rising daytime temperature can readily freeze if the temperature then drops below the freezing point.

Third-rail heaters have been effective in minimizing these icing problems on many transit systems. However, these ohmic heaters in general consume an inordinate amount of energy. An energy-efficient approach is to melt a thin layer of ice at the interface between the rail and the ice. This will break the strong adhesive bond between the rail and the ice layer. Once this bond has been broken, the rest of the unmelted ice can be easily removed by a mechanical scraper. Blackburn and St. John estimate the required interface melt thickness to be about 2 µm (1). The most desired mechanism for this approach would be to couple energy directly to an ice layer approximately 2 µm thick next to the interface between the rail and the ice with little or no energy being directly coupled to either the layer of ice more than 2 µm from the interface or the rail underneath. Unfortunately, this calls for a dramatic change in the physical properties of ice at the interface.

Even though there is some evidence that the ice properties are different at the interface compared with the bulk, such drastic differences are not anticipated. Hence, the next best solution is to have the energy source at the interface but located in the rail. The ice layer in immediate contact with the rail surface will be melted by the heat energy transferred from the rail to the ice. It is possible to achieve this rather easily by radio-frequency (RF) induction heating.

The basic concept of RF induction heating is rather straightforward (2,3). Essentially, a high-frequency alternating current is passed through a work coil in the close neighborhood of a load. This induces a current in the load. Its magnitude depends on the permeability of the load and falls off from the surface to the center of the work load with a rate of decrease that is higher at higher frequencies. It is this induced current that causes the rapid heating of the load.

For rails made of high-permeability materials, RF induction deicing is efficient in several respects. First, the heat is generated within the top few micrometers from the rail surface, where it is needed, and hence little is wasted by being transferred to the ambient. Second, modern RF generators have respectable conversion efficiencies. Third, this deicing system is very responsive in that rail surface temperature changes occur rapidly. The