Optimal Integrated planning of a Public Transit System

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Abstract: This paper is a study of the public transit systems. It includes an analysis of various regional transportation modes and arrives at optimal number of commuters patterns. The main focus is on the study of public transit systems issues in a medium size metropolitan environment. The thrust of this paper however is the establishment of criteria for public transportation needs of today and for the foreseeable future. While the final routes arrived are optimal, instead of using traditional optimization tools, an innovative approach in planning and organizing commuter travel using surveys is explained first and then the concept of TRUNK-BRANCH in public transit usage is presented in detail using a hypothetical example. Multi-modal approach is presented as possible solution to public transit. This paper delineates an approach in planning a public transit system that can be introduced in a small to medium scale environment. Attempts are made to address issues in public transportation in urban areas of any magnitude, from an average town, county partial system, to the 'one-line' origin-destination system.

INTRODUCTION

Studies on issues regarding public transit systems in a metropolitan environment are numerous. However, very few introduce any kind of a design concept, yet on a large scale. The basic approach of many of the research papers deals with fixing temporary commuting problems. The approach in this paper deals with issues in a metropolitan environment, and on a regional basis, embracing a wide range of problems and solutions. The establishment of criteria for public transit systems is presented by using the concept that gave birth to a Trunk-Branch system. Those commuter concentrations along certain routes, by way of survey information, may be the key to better planning of public transit. This approach is indeed the key element in design of a public transit transportation system for now and for the foreseeable future

The above-mentioned approach in planning a public transit system can be introduced on any scale anywhere, small scale, as well as large complex 'megalopolis' regions. Addressing issues in public transit in urban areas, of any magnitude, will be best served by the origin-destination survey method approach. The need of this research paper arose because the existing systems address minimal non-coordinated transportation routes, complicating commuter needs, wasting people's time and resources. Based on observations of mass transit in many metro-areas, it is obvious that in congested areas, where high-density population corresponds to heavy street traffic, a solution other than just buses and taxi-cabs needs to be found.

Subsequently many such metro-areas had to construct either elevated transport or underground subway systems, for moving people quickly within or out of the congested areas. For example, one method to avoid congestion at intersections could be the implementation of "ONE-WAY" streets that also avoids left turn accidents. The trend of inter-county commuting will continue to grow due to community allegiance, prohibitive housing prices, and extraordinary moving expenses. In this paper subway/metro, public transit/mass transit/rapid transit, lines /routes, riders/commuters are used interchangeably.

STUDY OBJECTIVES

This paper attempts to demonstrate an innovative approach in public transit design. No design of an actual system is provided however, except suggestions wherever appropriate. The main idea for our paper originated and prompted by the Orange County (O.C.) California bus system.

LITERATURE REVIEW

An effort has been made regarding transit design to locate trends similar to Trunk-Branch (T-B) design approach [9, 11]. The closest came to be the 'feeder' method, or bus lanes that share a common traffic route, referred to as 'trunk'. Most of the research papers do not address the issues of a basic design approach at all [3], nor the actual implementation by way of modes, multimodal systems based on a design, rather most of the papers deal with operational issues [3, 5]. Some of the research papers are sponsored by the bus industry promoters [1, 6, 7, 8, 11]. Public transport studies reviewed include primarily existing large systems. There is no consistent existing method that fits into T-B model. Many papers deal with surveys, except that some utilize U.S. Census information, seeking auto-less poor people, some relying on samplings, others on phone interviews, and or casual street survey, or any guessing techniques. Some research deals with car-bus accidents [12], frequency of stops, and idling engines which increase air pollution [8]. All transportation planning efforts in the U.S. under federal rules start with a multi-modal approach within a wide study corridor. Many studies – especially those assuming Bus Rapid Transit (BRT) or Light Rail (LRT) as an option – develop trunk-branch alternatives and have bus feeder services.

The authors of this paper believe that there is a growing demand for public participation in decision making as well as concern for safety and pollution issues. A primary factor regarding commuting and other uses in mind must be what's in the public interest. In addition, public transportation must provide maximum commuting possibilities to reach any destination, not only to work within a metropolitan area but also to the full satisfaction of the public.

METHODOLOGY

The concept, introduced herein, addresses an innovative approach, the process of which will be explained in the paragraphs that follow. Contrary to the present existing political scenario, which is to satisfy special interest groups to some extent, this research paper describes a simple method, by involving the general public to its maximum. Mass transit, as some identify correctly, its importance should originate with the public. The paper describes in detail how to obtain information from commuters. First we employ the SURVEY method on a low budget approach. Next is the description of the "Trunk-Branch" concept and design sequence. Analyzing data obtained from the public is the basis as it helps in commuter problems' solutions and then coming up with a "Dynamic Master Plan" which is essential to create and establish a range of transit solutions. The project is a guide for design, but it is not an actual means of implementation. Hence, this paper does not deal with detailed design of subway, or elevated systems; however, it introduces the three modes of public transit.

TRUNK-BRANCH (T-B) DESIGN SEQUENCE

T-B is a three-part design concept, components of which are:

1. Commuter surveys to establish a database
2. Trunk-Branch calculations and configurations
3. Dynamic Master Plan (DMP)

COMMUTER SURVEYS

Surveys provide a systematic approach. Public participation is critical. Steps in organizing surveys needed for public transportation may be overwhelming, nevertheless possible. Surveys are conducted to find out commuters' needs, (commuting by train, bus, etc.), and these are as good as people's intentions. Surveys, while voluntary, must be strongly encouraged. Surveys should be conducted everywhere, including schools (elementary, high schools, colleges), places of work, clubs, organizations and cultural centers. Surveys can be conducted in worship sites (churches, temples, mosques, etc.), and shopping centers, government centers, neighborhood centers, and any location where people gather. It does not make any difference what people use to move around, it is the need to know the facts for future consideration in planning road-networks and public transportation. The survey method description is a low budget deal; it can be conducted periodically, and is of enormous benefit.

Survey Instructions

Surveys are usually conducted in person, however surveys can also be conducted using carton boxes filled with forms and displayed in public places (sample form shown in Figure 1). First, ask people politely to fill out a form as instructed. Instructions to prospective commuters should include the following as a minimum: fill in for every trip that day, for each separate segment, per week that month and as many cards as needed for the current month only. Each month will be indicated by a different color for ease of identification. A method of transportation means how one gets from here to there, by bus, by car, on foot, bicycle, train, etc. Hence, by indicating one of the above means of transportation can help in identifying public needs. Any comments should be written on the back of a card. Survey data-base should provide a baseline for future critical decisions. Of interest are the additional participants in the SURVEY who are the population dispersed in and outside of metro-areas. This is to determine the density of commuters on segments of streets and roads everywhere, each and every month. That includes cities, county, regional centers, etc. The tendency and patterns of a commuting public can then be examined, and thus only by way of the survey method, as suggested above.

Please indicate major street intersections of trip origin and destination

(No name or address required)

Leaving from: ________________ Going to: ____________________

City / Town / Neighborhood: ________________ /________________

Please check one:

Time of trip: am (morning) noon (midday) pm (afternoon / evening)

Driving alone Driver + passenger Driver + multiple passengers

Means of transportation (please circle): car truck bike bus taxi train boat walking jogging cable car other
Please add comments on the back of this card

Figure 1: Sample Commuter Survey Information Card

It is imperative that critical that those all who commute any distance in the metropolitan area participate in the periodical surveys. Every effort must be made to maximize participation of the public that will yield a better view and understanding of the needs, and consequently a better basis to work with to construct a more valid "Trunk". It is the civic duty to help in planning a better public transit system. More data with public assistance will result in creating a more reliable data base; it will show people movement patterns (individual or group) in a particular segment and also on a wider scale. Any other survey methods like sampling methods provide a trend while T-B surveys indicate public needs. The authors are fully aware of some of the caveats and limitations of the sampling techniques used in this study such as non-randomness, lack of consistency for filling the forms as well as duplicates from the same person.

Trunk-Branch (T-B) Concept

The "Trunk-Branch" concept is based on a principle that any line originated at some point must have a destination, i.e. a terminal point. Any such line may run parallel to any other line (in vertical view, or by way of overlay). The implementation of this simple principle in a transportation network, where transit routes are of concern, allows route design that include, for the sake of speedy transit, selective express lines. This creates somewhat an advantage over existing route outlines (like bus routes crossing each other) as generally depicted by various bus companies schematics on their schedules.

T-B is based on results from analyzed survey data, and by manipulating any possible routes; it is therefore the surveys that are the essence of T-B. A number of possible T-B models may emerge as a result of available data. It is important because it shows where there is a concentration of prospective ridership, and therefore merging routes from branches. Thus T-B helps in resolving design matters in public transportation. The advantage of T-B configuration is that it allows the formation of express lines, or a combination of ‘express-local’ service. It lends itself best for an implementation of a true rapid transit system, (i.e. express or quick) for transportation of people. The T-B based design system benefits more riders as more public vehicles (bus or train) frequent the 'trunk', and thus serving the commuting public better. T-B is therefore providing a lead to an overall design for a comprehensive public transit system. It does not determine the medium of transportation to be instituted, rather the trend of population movement across a county, within a county, or outside the limits of a county.

The characteristics of T-B are that a branch is not considered a feeder, rather is an extension and a tree-like branch of a trunk. Secondly, branches merge into a Trunk, and then split back into branches where appropriate (see Figure 2). T-B is a demand oriented approach concept. It reflects the pattern of a commuting environment.

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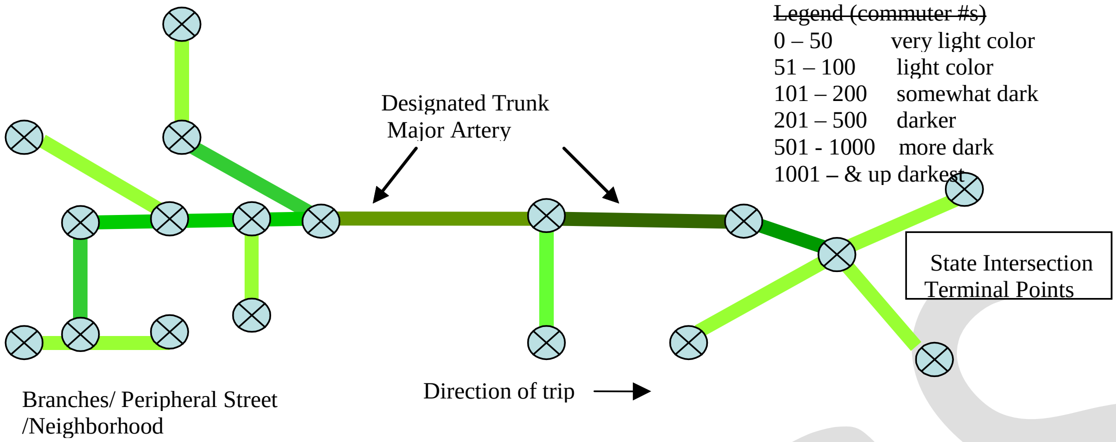


Figure 2: Trunk-Branch concept development illustration

Note: Overlapping, merging 'Branch' segments become a potential 'Trunk' by adding up the number of commuters based on the surveys, and expressed here in color (shades of gray to black); Any color shade does NOT represent commuters, but a range of numbers (i.e.,commuters); Lines represent streets/roads; The concept of 'Direction' in reality works both ways, i.e. people commute in any direction.

Defining T-B Network Procedures

T-B is unique in its approach by defining 'Nodes' at 2 points and its possible direction, confined to existing conditions, or by default, i.e. entering a desired X 'Node' value. That is important to state because most major street intersections are preferred. For instance, transit cannot be provided to a cul-de-sac. Trunks do not necessarily reflect modes of operation; however, they are best suited for rail systems. They benefit more riders (sub-trunk – frequent riders) thus better serving the commuting public, as more public vehicles (bus, train) frequent the 'trunk', and thus leading to an overall comprehensive design of a public transit system.

Processing of a Commuter Record

A preprocessing procedure may be used to convert intersection data to Global Coordinate System values, as defined by surveyor's maps, and confined by taking Global Positioning System (GPS) readings. A node 'N' is predetermined, based on default value, namely (x, y) coordinates of an intersection. Each defined 'Node' may have up to 3 possible outgoing attributes as indicated by node in-out arrows (see Figure 3).

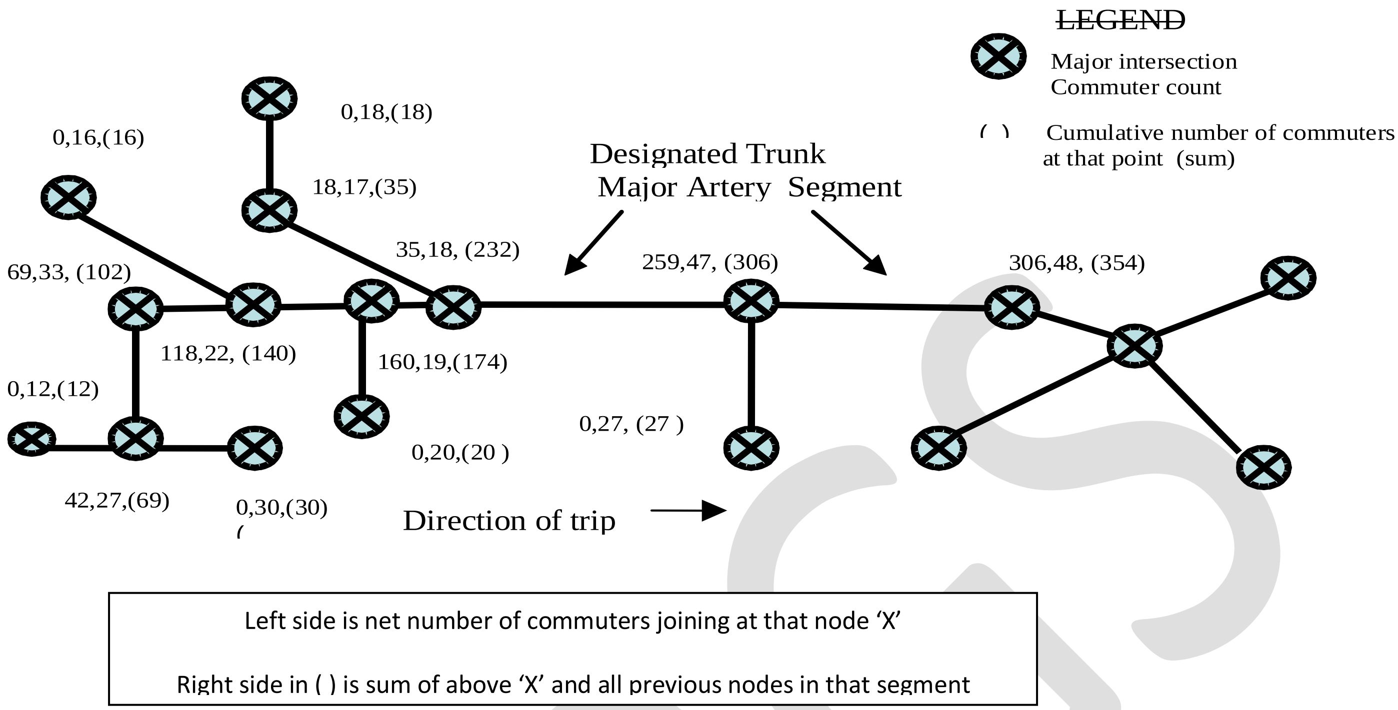


Figure 4: Trunk-Branch concept illustration example

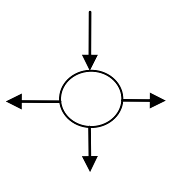


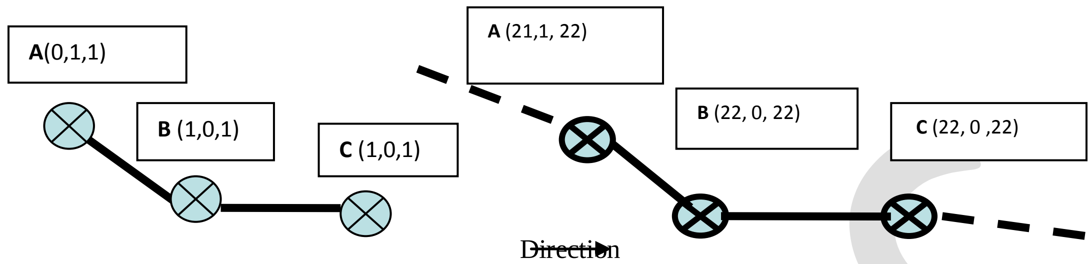
Figure 3: Three outgoing attributes

T-B is a class of its own. For clarification purposes a general case is presented here. For the purpose of T-B design, intersections are defined for convenience as conventional nodes. As indicated earlier a 'Node' identifies an intersection, or landmark, or point of interest, and is assigned a pair of coordinates (x, y). The number at the node for example 18,17,(35) where left number represents added commuters at that point (i.e., 'N'), and that in parenthesis is the sum of commuters at that point at a particular time. This is done for each and every commuter record processed (Figure 4). The whole operation is internal and according to an algorithm. Therefore the calculations depict a T-B path for each survey card (entered by a commuter). Based on the initial and final destination, an algorithm will find the direction of next 'Node', add to the sum, and then repeat the iteration process until the destination 'Node' is found. This essentially provides the algorithm for a software program that can be handled separately.

T-B legend shown in the example (Figure 2) is only a suggestion. It starts with a pale color (T-lines), the deeper the color of a segment between two nodes the heavier the concentration of commuters on that segment (between two nodes only). For a designer T-B intensity-shade of color may correspond to either single/multiple lanes or rail-tracks. A dark color of T means it reached saturation, and destined to be a Trunk. Different densities in color-shade may vary along any line, indicating commuter embarking or disembarking at a 'Node'.

Processing the Example

The cumulative progresses are shown in an example (Figure 5). Let A, B, C represent nodes (x, y coordinate address).



(a)Single record – one commuter

(b) When a record (or records) is added to the sum

Figure 5: Calculation example for A, B, C Nodes

Let A (i, j, k), B (i, j, k) and C (i, j, k) represent the formula for each node being processed where

i = previous number of commuters (from previous nodes)

j = present number of commuters (added at node)

k = total number of commuters (at that node)

A middle node assumes the following formulation:

$i_e = j_f + j_g$ where I_e is middle node, j_f is left side node, j_g is right side node

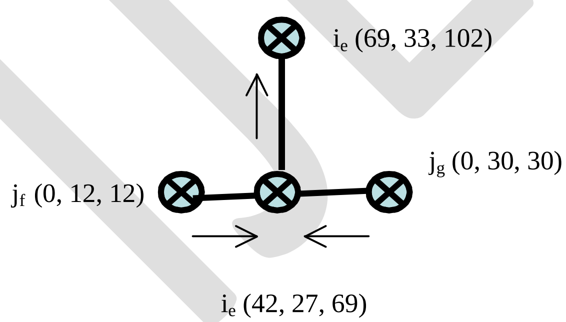


Figure 6: Segment of Figure 3 demonstrating concept calculations

The above example depicts a trip of one (or more) commuter within an overall T-B system (schematically). It does not matter where in the system the trip takes place.

Each individual commuter card is one new record. Therefore a one (1) is being added to the commuter count in calculating the number 1(sum), the new sum is then (1+ previous sum). It's entirely internal to the system, not visible to the user, and is part of the processing; it is presented here solely for explanation of the buildup method of a T-B network. As more commuter records are processed, the number to the left and inside parenthesis may or may not change, while the number in parenthesis (sum), serving as the color-change-argument, may change, as represented in the graphics (Figure 2). A dark color indicates a possible design consideration for a rapid, (express) efficient commuter's channel. The rationale of a 'RANGE' of numbers is an indicator for commuter density. That occurrence helps in defining a possible TRUNK.

The evolution of a single commuter record (survey card) as part of and into a complex T-B system has been demonstrated here. T-B concept can be applied to major highways (freeways/expressways) as well as rail and bus (surface, elevated, subways). It has many advantages. It allows different configuration study models for the purpose of designing a proper transportation network. Based on the survey study it helps to optimize the use of the overall system. T-B may indeed unintentionally coincide with a major route (thoroughfare). T-B thus serves as a guide in establishing a workable master plan, which in turn enables planning of an efficient public transit system. It can be shown that it is adaptable for use of an inter-modal arrangement of any magnitude.

This paper described software principles only. To accomplish the T-B processing procedures, a complete software package must be developed for use.

Dynamic Master Plan (DMP)

A DMP for Public Transit is an overall plan that serves to devise a layout part by part of an intended successful public transit system. DMP means a progressive, adjustable plan to satisfy the needs of the commuting public, implementation of which will eventually accomplish its purpose i.e., better commuting. DMP emanates naturally from a T-B configuration. It is the closest dealing with actual issues of implementation. By its very definition it should be updated periodically to reflect commuters needs, and it does not matter whether they use public transit or other means of transportation. It serves the public and appropriate authorities for future planning and statistics.

A master plan processor may use an adjustment formula to optimize route generation. Thus T-B has many advantages over other planning methods. Its design is independent of special implementation interests (buses, car lovers etc).

PUBLIC TRANSIT SYSTEMS

No particular transit system is being recognized as preferred for T-B design. Definitely no single mode of transportation can satisfy the needs of a metropolitan area. It only depends on the will of the public to invest in the best possible transportation infrastructure. As indicated below, three basic systems of transportation are identified in this paper [12]:

- Category A – Freeways or divided, controlled-access highways which serve only through traffic.
- Category B – Arterials, some of which are partially grade separated multilane roadways serving mostly through traffic.
- Category C – Urban streets, which serve primarily local traffic accessing the served area.

The most desirable system, true RAPID TRANSIT, is the underground system. A rail system independent of traffic lights, it takes off lots of cars from the streets and tons of health damaging fumes. It delivers fast, safe, and secure commuter service void of accidents, compared to roads, no ‘freeway rage’, reliable, controllable, and long lasting, but more costly to build.

SUMMARY, LIMITATIONS, CONCLUSIONS AND RECOMMENDATIONS

T-B is a viable method and could be the basis for design of a public transit system. Based on the surveys and T-B results, it allows transit professionals /administrators to make any adjustments and improvements, serves as a guide in any further developments, and enhancements needed to provide better service to the general public.

Metropolitan areas require multiple modes of transportation to satisfy their changing public needs. People happen to travel long distances. Examples of multiple needs are trips to work or business, medical, educational or cultural activities or appointments. Hence the outcome of any design has to be a system that satisfies the needs and convenience of commuters. Current systems do not address the needs of commuters and most deal just with ground surface transit like buses. Surface street transportation is getting saturated and causing damage to public health, loss of time and productivity. Contrary to other studies T-B is not involved in bus fare, bus comfort, or any guessing techniques like Census Bureau statistics. T-B is based on real data. In reviewing the studies of various transportation modes, including existing large transit systems (mostly buses) it is apparent that no matter what kind of system, none can provide the speed and safety to move large number of commuters [10,13]. There is no consistent existing method for planning that fits into a model or lends itself for T-B adaptation.

Federal/state support is unavoidable to construct the infrastructure. No county or large city can afford a massive mass transit construction. The cost to the federal government is evident everywhere [4]. There is a traditional obsession with cars, a costly addiction. Car culture is contributing to soil and water contamination by leaking oil and other fluids. Gasoline stations are a major problem in contamination of soil and air, thus adding to deadly air pollution mix. Also to be considered is the economic component of global warming. Car and bus manufacturers, oil barons and insurance companies are a problem, and the politically misguided public only worsens traffic conditions everywhere. Poor conditions on public vehicles as well as security concerns discourage people from using transit systems. Only quick, fast, safe and secure delivery of mass transit will solve commuters’ problems.

As for existing systems, changes and adaptations can be made, based on the T-B analysis. It may be necessary to consolidate present carriers for better efficiency or to replace them with an integrated system. It is not about eliminating anything in existence, it is about diversifying. Railroad commuter trains proved to be of benefit to distant housing dwellers [12]. There are public bus systems and specialized services like transport to medical facilities, which are in abundance. However there is a lack of coordination, causing time loss to commuters and unnecessary expenses. It takes will and courage to change for the better.

Conclusions

The problem of integrated planning of a public transportation system, which is essentially, an optimization problem, has been solved using an innovative approach of TRUNK_BRANCH approach which resulted in excellent results.

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