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EVALUATING LIGHT-RAIL TRANSIT ALTERNATIVES USING THE RATING AND RANKING METHOD

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ABSTRACT

Prior to beginning an analysis to evaluate a transportation alternative, the engineer or planner should consider a number of basic question and issues. These will assist in determining the proper approach to be taken, what data are needed, and what analytical technique should be used. Railroads contributed much to the growth of the Iraq Urban Area in the early 19-century. The movement of freight by rail transportation promises to be just as important to the future as it has been in the past. But during the last few decades there is no new rail service is implemented because the land use and economic impact will be tremendous. This paper studies the development of a High-Speed passenger rail link between airports and cities centers. Although rich in passenger rail history, Iraq has been without scheduled passenger trains since 1971. Further study is needed and is encouraged because of the potential benefit to the community. Possible benefits include: alternative transportation choices for citizens of diverse income levels; increased employment opportunities, and the integration and interconnection of a variety of modes of travel into the community. In this paper, the ranking and rating method is used for establishing the demand of transportation service. The result of this process furnishes the necessary input data to prepare an evaluation of the relative worth of alternative railway projects.

Keywords: rail transit, alternatives, planning, route design, railroads, transportation engineering.

1. INTRODUCTION

Railroad is one of the most important means of transportation. Every day, thousands of trains speed along railroad tracks throughout world. Some trains carry passengers. Others haul coal, grain, lumber, machinery, and other products on which people depend. Only ships carry heavier cargoes for longer distances. And only airplanes provide a faster means of public transportation than do railroads. A freight train can haul thousands of tons of goods across a continent. The fastest passenger trains in regular service travel at speeds of up to 186 miles per hour (m/h), or 300 kilometers per hour (k/h). In test runs, these trains have reached speeds of more than 250 mph (400 k/h). In many parts of the world, railroads are also called railways.

Railroads use a two-railed track to guide trains of cars along a permanent route. Trains therefore are not steered, unlike airplanes, automobiles, and ships. Powerful diesel-electric or electric locomotives move most trains along the track. However, older steam locomotives still haul a few trains in some parts of the world, such as Iraq, China and India.

Any layout that corresponds at least approximately to prototype railway practice can be operated in a realistic manner fairly easily all that is needed to treat railway operation as another aspect of the model railway, along with the scenery, which needs to be 'built'. To be able to operate a model railway in the most realistic way possible requires that operation be kept foremost in mind from the earliest design stages of model railway construction, however if the model railway is already partly or even completely built a reasonably realistic operating method can be still be devised.

The basic concept of an evaluation is simple and straightforward, but the actual process itself can be complex and involved. A transportation project is usually proposed because of a perceived problem or need. For example, a project to improve safety a railroad grade crossing is based on citizen complaints about accidents or time delays at the crossing site. In most instances, there are many way to solve the problem and each solution or alternative will result in a unique outcome in terms of project cost and results.

2. BASIC ELEMENTS OF RAILWAYS PLANNING

A master plan of any city is to make community life more comfortable, enjoyable, safe, and profitable. A good plan provides transportation facilities that enable people to get to and from stores, offices, and factories quickly and easily. It also provides enough recreation areas, schools, and shopping facilities (William, 2003).

The railways planning like the transportation planning process, it comprises seven basic elements. The information acquired in one phase of the process may be helpful in some earlier or later phase, so there is a continuity of effort that finally results in a decision. The elements in the process are (Garber and Hoel, 2009):

a) Situation definition.
b) Problem definition.
c) Search for solutions.
d) Analysis of performance.
e) Evaluation of alternatives.
f) Choice of project.
g) Specification and construction.

Railroad planning is a continuous process driven by the need to provide a safe and efficient system of transportation facilities and services to the public. There are a number of significant forces, which influence the delivery of transportation projects and services and the process must be sufficiently open to allow for fair hearing of the various positions of the client population (Oglesby and Hicks, 1982) and (O'Flaherty, 1988).

The process of transportation planning begins with an assumed land use and then projects future traffic volumes. Planning of any transportation project is not the simplest of tasks. A large number of people when planning a layout imagine that they can fit much more route into a given space than will actually fit there. The problem is that drawing a scale plan is a relatively time consuming and difficult task that many layout planners do not undertake. Even where a scale drawing is made, it is extremely easy to get something slightly out of correct scale and make it look like you can fit something in that just wont fit when you actually start construction.

The long-range transportation plan requires analyzing the existing transportation network in terms of current and projected future needs and developing a program of projects to address these needs. In order to accomplish this, the plan must outline a transportation study area.

3. RAILWAYS ROUTE DESIGN

Railway engineering generally consists of cuts and fills for railway formation, layer works to support the stone ballast, track work, drainage culverts, and bridges. On certain railway lines, electrical overhead supply lines are required for electrical traction, while signaling systems are normally provided on long distance lines. For station layouts and industrial sidings a system of points and crosses enables the efficient shunting and staging of individual rolling stock or train sets. The new project should include the following services (Riley, 1995):

- Operation of railway systems
- Environmental Engineering
- Quantity surveying
- Project Management
- Earthworks design for railway formation
- Ballast, sleeper and track work design
- Drainage and sub-soil drainage
- Bridge design
- Electric supply line design
- Signaling design
- Station and industrial yard layout designs
- Preliminary designs and feasibility studies for suburban lines as part of a wider transportation corridor
- Railway and bridge maintenance plans
- Civil designs for employment creation projects

The rails and crossties that make up railway track are laid along a roadbed that is, land that has been prepared as a foundation for the track. The roadbed follows the route planned for a railroad. Mainline routes link major cities. Branch lines extend between main lines and various places not served by main lines, such as small communities or mining sites. Many main lines consist of two or more tracks laid side by side. Such multiple tracks enable trains to travel in opposite directions on the same line at the same time. Single-track lines must be equipped with sidings at various points along the route. A siding is a short track alongside a main or branch line to which one of two meeting trains are switched until the other train passes (William, 2003).

The track and roadbed, together with such other railway structures as tunnels and bridges, are sometimes referred to as the roadway. In addition to the roadway, railways own a certain amount of land on both sides of the roadway. This land and the roadway make up a railroad's right of way. Most crossties, or ties, are spaced about 21 inches (53 centimeters) apart. The ties average about 3,000 per mile (1,900 per kilometer). There are two types of ties wood ties and concrete ties (Figure-1).

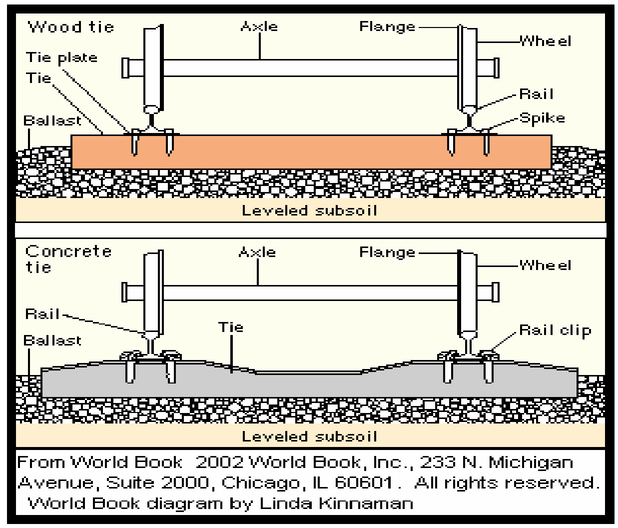

Figure-1. Train wheels and trucks (William, 2003).

When wood ties are used, two steel tie plates are placed on top of each tie, one plate near each end of the tie. Each plate has a wide groove that is shaped to hold the bottom of the rail. Steel spikes are driven through holes in the plates. The spikes hook over the bottom of the rail and keep it firmly fastened to the tie.

Concrete ties do not have plates and spikes. Instead, plastic pads replace the plates, and two steel bolts with spring clips hold the base of the rail firmly to the tie.

The spikes or bolts must be the same distance a part on each tie so that they hold the rails the same distance a part all along the track. This uniform distance between rails is called the gauge. Every country has a standard gauge for all its main rail lines. Most countries also have this same standard gauge for most branch lines. In this way, any locomotive or car can travel on almost any track in the country. But the standard gauge varies from country to country. Australia, Canada, Mexico, the United States, and most European nations have a standard gauge of 4 feet 8 1/2 inches (1.44 meters).

In the United States, steel mills produce rails in 39-foot (12-meter) or 78-foot (24-meter) lengths. Little new track is laid, and so new rails are used mainly to replace existing track. Much existing track consists of 39-foot lengths of rail joined end to end by pieces of steel called joint bars or fishplates. The joint bars are fastened to the rails by bolts that pass through holes in the bars and in the sides of the rail (Halberstadt, 1995).

In building a roadbed, civil engineers use special instruments and machinery to make the land as smooth and level as possible. This process is called grading. Most roadbeds are then covered with a layer of ballast, which consists of such materials as gravel or crushed stone. Ballast holds the ties in place and so helps keep the track stable. Ballast also helps distribute the weight of passing trains and gives them a degree of cushioning. Trains thus ride more easily than they would over bare ground. Ballast also promotes drainage of rainwater and slows the growth of weeds.

Before constructing the roadbed, engineers plan a route with the least possible grade and curvature. Grade refers to the steepness of the land. Curvature refers to the number and sharpness of curves along the route. The ideal railroad route lies across perfectly flat land. Track laid along such a route has little or no grade or curvature. Freight trains can easily carry heavy loads along the track, and passenger trains can travel at top speed. Steep grades, on the other hand, make it difficult for a train to carry heavy loads or travel at a high speed. If a route passes through hilly or mountainous country, engineers lay track around steep grades instead of over them. The track thus has many curves. Curves reduce a train's speed but do not prevent it from carrying heavy loads.

A route through a mountain range might require so many curves that travel along the route would be extremely slow. Engineers therefore sometimes build railways tunnels through mountains. They also construct railroad bridges to span chasms and rivers. Tunnels and bridges are also built to extend railroad routes under or across bays and other bodies of water.

4. RAILWAYS TYPES

Railways provide two main types of service: (1) passenger service and (2) freight service. The importance of each type of railways service varies from country to country (Jackson, 1992).

4.1 Passenger service

Railways operate two main types of passenger trains: commuter trains and intercity trains. Commuter trains carry passengers between large cities and the surrounding suburbs (Figure-2). Most of these trains are made up of a locomotive and a number of coaches. Intercity trains make longer runs than most commuter trains do. The longest intercity runs cover great distances and take several days to complete. As a result, many intercity passenger trains have special cars, such as dining cars and sleeping cars, in addition to coaches.

Since the 1940's, the number of rail passengers has declined sharply in many industrial countries, as more and more people travel by automobile and airplane. For example, railways in the United States now carry less than 1 percent of all intercity passenger traffic. In some countries, however, passenger trains have not faced such strong competition from other forms of transportation. People in China, India, Japan, and most European countries still rely heavily on trains for intercity transportation. And even in the United States, thousands of people who live in suburban areas ride commuter trains into major cities.

A majority of rail passengers ride commuter trains. Each working day, these trains carry great numbers of suburban residents to and from work in such large cities as London and New York City. Commuter trains also serve many other cities throughout the world, including Berlin, Chicago, Johannesburg, Moscow, New Delhi, Paris, Sao Paulo, Tokyo, and Toronto. Some intercity trains also serve commuters. It takes up to 1,000 automobiles to carry as many commuters as one commuter train can carry. Commuter trains thus help relieve rush-hour traffic jams on city highways. By reducing the number of automobiles in use, commuter trains help conserve fuel. They also help reduce air pollution caused by exhaust fumes (Halberstadt, 1995).

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Figure-2. Commuter trains (William, 2003).

Some countries have unusually fast; efficient intercity passenger trains (Figure-3). The fastest passenger trains in the world operate in France and Japan. Trains in both countries travel up to 186 mph (300 kph) between stops. They may average more than 160 mph (260 kph). High-speed trains also serve cities in Germany, the United Kingdom, and other European countries. Some of the Japanese and European high-speed trains offer a number of luxury services, including gift shops, telephones, and meals served at the passengers' seats.

Some Canadian intercity trains, called Corridor Trains, also provide luxury service. One of these trains carries passengers between Toronto and Montreal-a 335-mile (539-kilometer) journey-at an average speed of about 80 mph (130 kmph).

In the early 1900's, there were thousands of passenger trains in the United States, linking almost all U.S. cities. Today, only about 125 daily intercity trains serve the entire country. The only high-speed trains operating in the United States are Acela and Metro liners.

Acela, which can reach a speed of 150 mph (240 kmph), service several cities in the eastern United States. Metro liners, electric-powered trains that run between New York City and Washington, D.C., can achieve a top speed of about 130 mph (210 kmph).

Figure-3. Intercity trains (William, 2003).

4.2 Freight service

In many countries, most of the income earned by railways comes from hauling freight. Railways provide the most inexpensive method of land transportation over long distances. Trains are used extensively to carry such bulk goods as chemicals, coal, grain, iron ore, and petroleum. They also carry such manufactured goods as automobiles and television sets, and such agricultural products as fruits, vegetables, and meats. Some of the cars on a freight train are empty cars being moved to various points for reloading (William, 2003).

Railways use many types of cars and freight-handling equipment. Bulk materials, such as coal and ores, travel in open cars with hatches (doors) underneath. Such cars can be emptied quickly through these doors. Powdered materials, such as cement, travel in cars that are pressurized steel containers. The cars are loaded and unloaded using air pressure that pumps the material in or out through pipes. Chemicals, gasoline, milk, and other liquids are carried in tank cars. Refrigerated cars transport fruits, vegetables, and meats. Special railroad cars with two or three decks are used to carry automobiles (William, 2003).

The longest freight trains have 200 or more cars. In the United States, a typical freight train has about 80 cars and carries about 5,000 tons (4,500 metric tons) of goods.

Railways in many countries carry more freight today than ever before. However, railways haul a smaller share of the total freight traffic than in the past. For example, in 1929, railways handled almost 75 percent of all the freight carried between U.S. cities. Today, they carry about 40 percent of all intercity commercial freight (Halberstadt, 1995).

5. RAILWAYS TRAFFIC CONTROL

Railways use signals and various other means to control train traffic. The chief purpose of traffic control is to prevent accidents. But it also helps make railroad operations speedier and more efficient.

Most railroad signals consist of colored lights alongside or over the track. Each color has a different meaning. For example, red means stop, and green means precede. Yellow alerts the train to reduce speed, to stop at the next signal, or to maintain a lower speed (Riley, 1995).

The signals and other means a railroad uses to control traffic are part of its signal system. Most railways have adopted some form of the block signal system. This system is designed chiefly to keep a safe distance between trains traveling on the same track. In block signal systems, a railroad line is divided into lengths of track called blocks. Most blocks range from 1 to 2 miles (1.6 to 3.2 kilometers) long. Only one train may be in a block at a time. Colored light signals control entry to the block. When a train is in the block, the signals warn other trains to stop. No train may proceed from one block to the next without an all-clear signal. Block signals may be either automatic or manual (hand-operated).

Automatic block signal systems are the most common type of block systems used today. In an automatic block system, an electric current, also called a track circuit that flows through the rails, operates the signals. A train entering a block short-circuits this current, causing the signal that guards the block to turn red. As soon as the train leaves the block, the signal returns to yellow, meaning "all clear." Many automatic block systems also have interlocking controls. Interlocking controls set multiple track switches at one time to ensure a safe path for the train to follow through complex junctions (Riley, 1995).

A remotely controlled signal system is called Centralized Traffic Control (CTC). Signals and switches on the line are controlled from a central dispatch station. This station has one or more electronic diagrams that show the present location of every train on a line. CTC operators study the diagrams to decide how to route the trains as safely, speedily, and efficiently as possible. The operator's direct train traffic by setting the necessary signals and switches. Modern forms of CTC, with advanced computers and safety systems, are referred to as centralized dispatching. Such dispatching makes it possible for railways to use single tracks efficiently for two-way traffic. If two trains are headed toward one another on the same track, a dispatcher switches one of the trains to a siding until the other passes. CTC also makes use of interlocking controls (Vance, 1995).

Manual block signal systems require operators at various points along the line to control the signals. Each operator is responsible for the movement of trains within one or two blocks and informs other operators by telephone whether a block is occupied or clear. The possibility of human error makes manual signal systems less reliable than automatic systems. Some manual block systems have interlocking controls. These controls ensure that switches in complex combinations can only be set safely. They also give signals to approaching trains to prevent derailment or collision.

Many railways are experimenting with advanced train control systems, also known as positive train control, to improve safety and efficiency. In addition to signal lights alongside their tracks, some railways have signals providing the same information on panels in their locomotives. These signals may also work in connection with safety devices. One such device is the automatic train stop (ATS). The ATS puts on a train's brakes automatically if the engineer fails to notice a stop signal. Another safety device, called automatic train control (ATC), automatically controls a train's speed. If the engineer fails to notice a caution signal, the ATC puts on the brakes to slow the train to the required speed. The device also stops the train if necessary (Vance, 1995).

Many railways use advanced communications systems to help control the movement of trains. Two-way radio systems on trains enable crewmembers to communicate from one end of the train to the other. Train crews also use two-way radio systems to communicate with distant dispatching centers. Railways trace the exact locations of their trains and of individual cars by using transponders (electronic transmitting devices) as tags. Trackside equipment sends and then receives radio signals from the transponders. Satellite-based tracking of trains using the Global Positioning System (GPS) also helps railways improve train control (William, 2003).

6. OBJECTIVES OF EVALUATION

Garber and Hoel (2009) reported that the objective of an evaluation is to furnish the appropriate information about the outcome of each alternative so that selection can be made. The evaluation process should be viewed as an activity in which information relevant to the selection is available to the person or group that will make decision. An essential input in the process is to know what information will be important in making a project selection.

There are many methods and approaches for preparing a transportation project evaluation, and each one can be useful when correctly applied. Evaluation can also be made after a project is completed to determine if the outcomes of the projects are as had been anticipated. Post facto evaluation can be very helpful in formulating useful for evaluating similar projects elsewhere or is making modifications in original designs.

7. IDENTIFYING PROJECT STAKEHOLDERS

A transportation projects affect a variety of groups in different ways. In some instances, only one or a few groups involved; in other cases, many factions have an interest. Examples of groups that could affected by a transportation project include the system users, transportations management labor, citizens in the community, business, and local, state, and national government each represents will influence the evaluation process itself (Garber and Hoel, 2009).

For smaller, self-contained projects, those groups with some thing to gain or lose the project-the stakeholders-will usually be limited to the system users and transportation management. For larger, regional-scale transportation projects, the number and variety of stakeholders will increase because the project will affect many groups in addition to the users and management. For example, a major project could increase business in the downtown area, or expanded construction activity could trigger an economic boom in the area. If the viewpoint is that of an individual traveler or business, the analyses can be made on narrow economic grounds.

8. SELECTING AND MEASURING EVALUATION CRITERIA

A transportation project is intended to accomplish one or more goals and objectives. The numerical or relative results for each criterion are called measures of effectiveness. For example, in a railroad grade crossing problem, if the goal is to reduce accidents, the criteria can be measured as the number of accidents expected to occur for each of the alternatives considered. If another goal is to reduce waiting time, the criteria could be the number of minutes per vehicle consumed at the grade crossing (Herenton, 1993).

Criteria selection is a basic element of the evaluation process because the measure used becomes the biases on which each project is compared. Criteria not only must be relevant to the problem but also must have other attributes as well. They should be easy to measure and sensitive to changes made in each alternative (Garber and Hoel, 2009).

9. MEASURES OF EFFECTIVENESS

One approach in measuring of effectiveness is to convert each measure of effectiveness to a common unit, and then, for each alternative, compute the summation of all measures. A common unit is money, and it may be possible to make transformation of the relevant criteria to equivalent dollars and then compared each alternative from an economic point of view. For example, if the cost of an accident known and the value of travel time can be determined, then for the rail road grade crossing problem, it would be possible to compute single number that would represent the too cost involved for each alternative, since construction, maintenance, and operating cost are already known in dollar terms, and the accident and time costs can be computed using conversion rates.

A second approach is to convert each measure of effectiveness to numerical. A single number can be calculated that represent the weighted average score of all measures of effectives were considered. This approach is similar to calculate grades in course. Measures of effectiveness should be independent each other of summation procedure (such as adding grades) is to be in the evaluation.

A third way is to identify the measures of effectiveness for each alternative in matrix form, with no attempt made to combine them. This approach furnishes

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the maximum amount of information without prejudging either how the measures of effectiveness should be combined or their relative importance (Garber and Hoel, 2009).

10. EVALUATION PROCEDURES AND DECISION MAKING

The decision maker typically needs to know what that costs of projects will be; in many instances, this alone weight determined the outcome. And the decision maker will also want to know if the proposed project is likely to produce the state results it may be necessary to carry out sensitivity analysis that shows range of values rather than number. The decision maker also may wish to know if all alternatives have been considered and how they compare with the one being recommended. The decision maker will also want to know if the proposed project is likely to produce the state results it may be necessary to carry out sensitivity analysis that shows range of values rather than number. The decision maker also may wish to know if all alternatives have been considered and how they compare with the one being recommended. The decision maker may want to know the cost to highway users as the result of travel delays during construction (Herenton, 1993).

11. EVALUATION BASED ON ECONOMIC CRITERIA

To begin the discussion of economic evaluation, it is helpful to consider the relationship between the supply and demand for transportation services. As the cost of using the facility decreases, the number of vehicle per day will increase. This relationship is shown schematically in Figure-4, and represents the demand curve for the facility for a particular group of motorists.

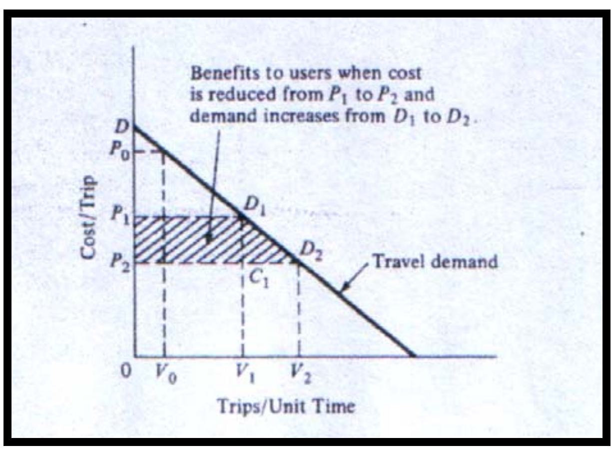

Figure-4. Demand curve for travel on a given facility (Garber and Hoel, 2009).

A demand curve could shift upward or downward and have a different slope for users with different incomes or for various trip purposes. If the curve moved upward, it would indicate a greater willingness to pay, reflecting perhaps a group with a higher income. If the approaches horizontal, it would indicate that demand is elastic and a small change in price would result in a large change in volume. If the slope approached vertical, it would indicate that the demand is inelastic; a large change in price has little effect on demand. As in example, the price of gasoline is said to be inelastic because people seem to drive equally as often after gas prices increase as before the increase. The formula for user benefits is (Garber and Hoel, 2009):

$$B_{2,1} = 0.5(P_1 - P_2)(V_1 + V_2) \quad (1)$$

where:

$B_{2,1}$ = net benefits to transport users
P_1 = user cost of unimproved facility
P_2 = user cost of improved facility
V_1, V_2 = the number of trips per unit time

12. ELEMENTS OF COST

The cost of transportation facility improvement includes two components: *first cost* and *continuing costs.* Those costs are common to both projects can be excluded. The first cost for a highway or railway transit project may include engineering design, right of way, and the construction. Each transportation project is unique, and the specifics of the design will dictate what items will be required and at what cost. Continuing costs include maintenance, operation, and administration.

Expenses for administration or other overhead charges are usually excluded in an economic evaluation because they will be incurred regardless of whether or not the project is selected. Other excluded costs are those have already been incurred. These are known as *sunk costs* and as such are not relevant to the decision of what to do in the future since these expenditures have already been made. For most capital projects, a service life must be determined and a salvage value estimated. *Salvage value* is the worth of an asset at the end of its service life. Suggested service lives for various facilities can be obtained from various transportation organizations, such as the American Association of State Highway and Transportation Official and the American Public Transit Association (Garber and Hoel, 2009).

Three commonly used measures of user costs are included in a transportation process evaluation: costs for vehicle operation, travel time costs, and costs of accidents. These costs are sometimes referred to as *benefits*, the implication being that the improvements transportation facility will reduce the cost for the users that is, lower the perceived process as shown on the demand curve and result in a user benefit.

13. COST ESTIMATES

Conceptual level cost estimates should be prepared for each item listed as a corridor requirement. All parties should be aware that conceptual level cost estimates would carry a large contingency factor (typically 30 - 35 percent), because average unit costs are usually used and detailed design analysis has not been done. Review of the various cost estimates will typically result in some projects being deemed too expensive for the benefits produced, and requests to look at other alternatives will be made. It can be expected that a typical transportation plan will involve a number of options being coasted before all parties can agree on some of the most cost-effective solutions (FRA, 2005).

A corridor transportation plan would typically summarize the various project costs into four basic categories (FRA, 2005):

A. Recapitalization: This category would include repairs or replacement of life- expired capital assets that would be necessary under any circumstance to simply continue existing levels of service and operations. Typical elements might include:

a) Bridge replacements (undergrad and overhead)
b) Replacement of signal and communications cable
c) Replacement of right-of-way fencing
d) Replacement of station roofs, platforms, etc.

B. Trip time improvements: This category would include items that are solely intended to reduce trip times for corridor passenger train service. Typical elements might include:

a) Curve realignments
b) Concrete ties and welded rail installation
c) Grade crossing removal or improvements
d) Install a new cab signal system in order to operate at more than 79 mph
e) Reconfigure a junction or station for higher speeds
f) Purchase higher-speed rolling stock
g) Install an electric traction system.

C. Capacity-related improvements: This category would include items that are required to increase the capacity of the corridor in order to allow increases in traffic by all users of the corridor. Typical elements might include:

a) New passing tracks
b) Additional main tracks
c) Interlocking reconfigurations
d) Additional station platforms
e) New or expanded maintenance facilities
f) Install high-level ADA-compliant passenger platforms
g) Revise signal locations and aspects.

D. Other projects: This category would include other corridor related projects that do not fall within any of the other three categories. Typical projects might include:

a) Purchasing new commuter rolling stock
b) Building new commuter stations
c) Constructing multi-modal terminals
d) Constructing additional parking facilities
e) Improving freight clearances

14. ECONOMIC EVALUATION METHODS

An economic evaluation of a transportation project is completed using one of the following methods: present worth (PW), equivalent uniform annual cost (EUAC), benefit cost ratio (BCR), or internal rate of return (ROR).

Since transportation projects are usually built to serve traffic over a long period of time, it is necessary to consider the time-dependent value of money over the life of a project.

Present worth (PW): is the most straightforward of the methods, since it represents the current value of all the costs that will be incurred over the lifetime of the project. The general expression for present worth of a project is:

$$PW = \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} \quad (2)$$

where

C_n = facility and user costs incurred in year *n*
N = service life of the facility (in year)
i = rate of interest

Net present worth (NPW) is the present worth of a given cash flow that has both received and disbursements. The use of an interest rate in an economic evaluation is common practice because it represents the cost of capital. It is helpful to use a cash flow diagram to depict the costs and revenues that will occur over the lifetime of a project. Time is plotted as the horizontal axis and money as the vertical axis, as illustrated in Figure-5. We can calculate the NPW of the project by using the following equation:

$$NPW = \sum_{n=0}^{N} \frac{R_n}{(1+i)^n} + \frac{S}{(1+i)^n} - \sum_{n=0}^{N} \frac{M_n + O_n + U_n}{(1+i)^n} - C_o \quad (3)$$

where

C_o = initial construction cost
n = a specific year
M_n = maintenance cost in year n
O_n = operating cost in year n
U_n = user cost in year n
S = salvage value
R_n = revenues in year n
N = service life, years

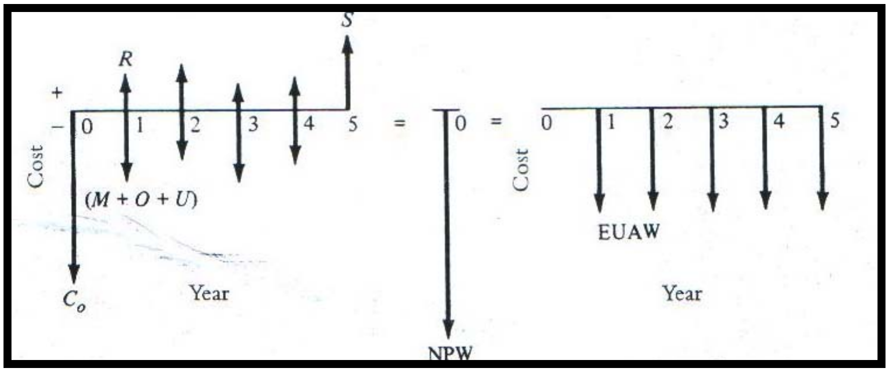

Figure-5. Typical cash flow diagram for a transportation alternative and equivalence as net present worth of annual cost (Garber and Hoel, 2009).

Equivalent uniform annual worth (EUAW) is a conversion of a given cash flow to a series of equal annual amounts. If the amounts are considered to occur at the end of the interest period, then the formula is:

$$EUAW = NPW\left[\frac{i(1+i)^N}{(1+i)^N - 1}\right] = NPW(A/P - i - N) \quad (4)$$

Similarly,

$$NPW = EUAW\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] = EWAW(P/A - 1 - N) \quad (5)$$

where

EUAW = equivalent uniform annual worth
NPW = net present worth
i = interest rate, expressed as a decimal
N = number of years
A/P = capital recovery factors

The benefit-cost ratio (BCR) is a ratio of the present worth of net project benefits at a net project costs. This method is used in situations where it is desired to show the extent, which an investment in a transportation project will result in a benefit to investor to do this; it is necessary to make project comparisons to determine how the added investment compares with the added benefits. The formula for BCR is:

$$BCR_{2/1} = \frac{B_{2/1}}{C_{2/1}} \quad (6)$$

where

$BCR_{2/1}$ = reduction in user and operation costs between higher cost alternative 2 and lower cost alternative 1, expressed as PW or EUAW
$C_{2/1}$ = increase in facility costs, expressed as PW or EUAW

Correct application of the BCR method requires that costs for each alternative be converted to PW or EUAW values. The proposals must be ranked in ascending order of capital cost, including the do-nothing alternative, which usually has little if any initial cost. If the higher cost alternative yields a BCR less than 1 it is eliminated and the next higher cost alternative is compared with the lower cost alternative. If the higher cost alternative yields a BCR equal to or greater than 1, it is retained and the lower cost alternative is eliminated. This process continues until every alternative has been compared. The alternative selected is the one with the highest initial cost and a BCR of 1 or more with respect to lower cost alternatives and a BCR less than 1 when compared with all higher cost projects.

The internal rate-of-return (ROR) method determines the interest rate, which the PW of reductions in user and operation costs $B_{2/1}$, equals the PW of increases in facility costs $C_{2/1}$. If the ROR exceeds the interest rate (referred to as minimum attractive rate of return), the higher cost project is retained. If the ROR is less than the interest rate, the higher pried project is eliminated. The procedure for comparison is similar to that used in the BCR method.

15. EVALUATION BASED ON MULTIPLE CRITERIA

Many problems associated with economic methods limit their usefulness. Among these are:

a) Converting criteria values directly into dollar amounts.
b) Choosing the appropriate value of interest rate and service life.
c) Distinguishing between the user group that benefit from a project and those that pay.
d) Failing to distinguish between groups that benefit and those that lose.
e) Considering all costs, including external costs.

For these reasons, economic evaluation methods should be used either in narrowly focused projects or as one of many inputs in larger projects.

15.1 Rating and ranking

Numerical scores are helpful in comparing the relative worth of alternatives in cases where criteria values cannot be transformed into monetary amounts. The basic equation is as follows (Garber and Hoel, 2009):

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$$S_i = \sum_{j=1}^{N} K_j V_{ij} \tag{7}$$

where

S_i = total value of score of alternative i
K_j = weight placed on criteria j
V_{ij} = relative value achieved by criteria j for alternative I

15.2 Case study

The construction of a light-rail transit line from Baghdad International Airport to the Central Railroad Station is considered as shown in Figure-6.

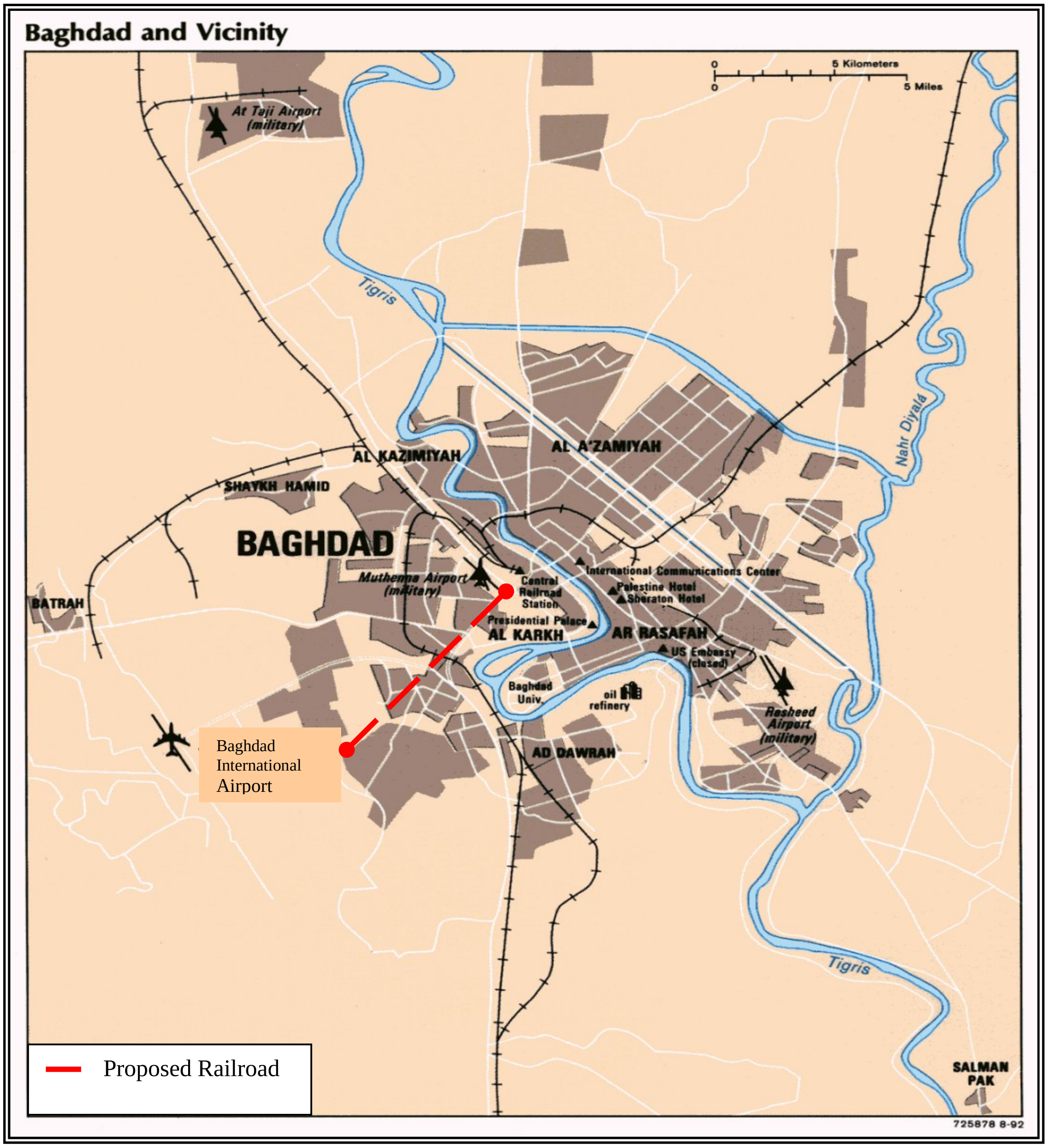

Figure-6. Baghdad city map.

The designer wishes to examine four alternative alignments, each of which has advantages and disadvantages in terms of cost, rider ship, and service provided. The alternatives differ in length of the line, location, types of vehicles used, seating arrangement, operating speeds, and number of stops. Estimated values achieved by each criterion for each of the four alternatives are shown in Table-1. The designer wants to evaluate each alternative using a ranking process in order to determine which project should be selected.

The following steps show the procedure of ranking and rating method of evaluating the alternatives as presented by Garber and Hoel (2009). A program is written for this purpose, which is illustrated in Figure-7.

First of all we should develop the alternatives that will be tested. In this case four alternatives have been identified as feasible candidates. These vary in length from 7 to 10 miles. The alignment, the amount of the system below, at, and above grade, vehicle size, headways, number of trains, and other physical and operational features of the line are determined in this step.

Then determine the relative weight for each objective. This step requires a subjective judgment on the part of the group making the evaluation and will vary among individuals and visited interest. One approach is to allocate the weights on a 100-point scale (just as would be done in developing final grade average for a course). Another approach is to rank each objective in order of importance and then use a formula of proportionality obtains relative weights. In this example, the objectives are ranked as shown in Table-2. Assigning the value n to the highest ranked alternative, n - 1 to the next highest, and so forth and computing a relative weight as follows determine the weighting factor:

$$K_j = \frac{W_j}{\sum_{j=1}^{n} W_j} \quad (8)$$

where

Kj = weighting factor of objective j
Wj = relative weight for objective j

Compute a score and ranking for each alternative, which is illustrated in Table-3. The score for each alternative is computed by considering each measure of effectiveness and awarding the maximum score to the alternative with the highest value and a proportionate amount to the other alternatives. Consider the first criterion, return on investment.

The total point score indicates that the ranking of the alternatives in order of preference is IV, III, II, and I. The fourth alternative will bear further investigation prior to making decision than others.

Ranking and rating evaluation is an attractive approach because it can accommodate wide variety of criteria and can incorporate various viewpoints. Reducing all inputs to a single number is a convenient way to rate the alternatives. The principal disadvantages that the dependence on a numerical outcome masks the major issues underlying the selection and the tradeoffs involved. Another problem with ranking methods is that the mathematical form for the rating value (Equation 7) is a summation of the products of the criteria weight and the relative value. For this mathematical operation to be correct, the scale of measurement must be a constant interval (for example, temperature). If the ranking values are ordinal (such as the numbering of a sport team), the ranking formula cannot be used.

Table-1. Estimated values for measures of effectiveness.

Number	Measures of effectiveness	Alternatives			
		I	II	III	IV
1	Annual return on investment %	15	11	12.5	13.5
2	Daily rider ship (1000s)	17	23	20	25
3	Passengers seated in peak hour (%)	28	35	50	45
4	Length of line (mi)	7	10	8	9
5	Auto drivers diverted (1000s)	1.5	2	3	3.5
6	Average door-to door auto trip speed mi/hr	15.9	16	20.3	18
7	Average door-to door transit trip speed mi/hr	21.5	20	16	15.8
8	Annual transit passengers (millions)	160	154.5	165.0	168.5

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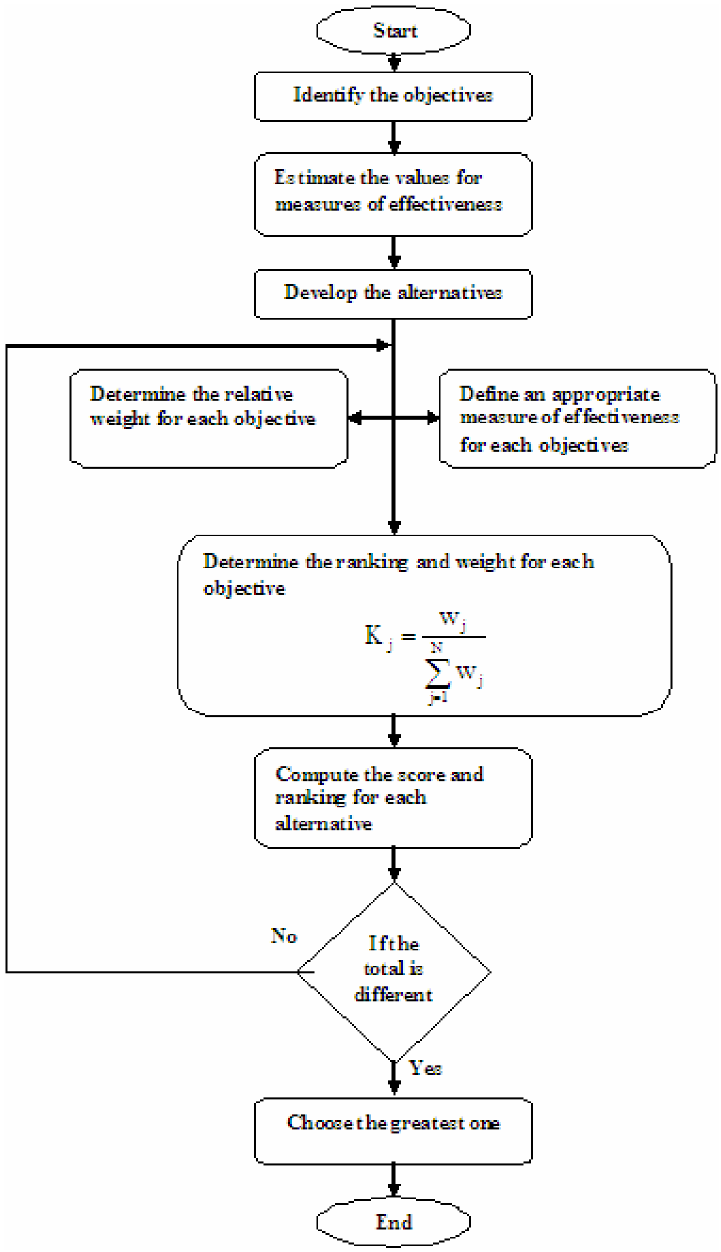

Figure-7. Flowchart of the developed method.

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Table-2. Ranking and weights for each objective.

Objective	Ranking	Relative weight (Wj)	Weighting factor (X100)
1	1	8	19
2	2	7	16
3	3	6	14
4	3	6	14
5	4	5	12
6	5	4	9
7	5	4	9
8	6	3	7
Total		**43**	**100**

Table-3. Point score for candidate transit lines.

Measures of effectiveness	Alternatives			
	I	**II**	**III**	**IV**
1	19.0	13.9	15.8	17.1
2	10.9	14.7	12.8	16.0
3	7.8	9.8	14.0	12.6
4	9.8	14.0	11.2	12.6
5	5.1	6.9	10.3	12.0
6	7.0	7.1	9	8
7	9.0	8.4	6.7	6.6
8	6.6	6.4	6.9	7.0
Total	**75.2**	**81.2**	**86.7**	**91.9**

16. CONCLUSIONS

The evaluation process for selecting a transportation project has been described above. Rating and ranking has been presented that it can assist a decision maker in making a selection. The most important attribute of an evaluation method is its ability to correctly describe the outcomes of a given alternative. The following comments are concluded:

a) The evaluation process begins with a statement of goals and objectives of the proposed project, and these are converted into measures of effectiveness.
b) Evaluation methods differ by the way in which measures of effectiveness are described.
c) Numerical ranking methods require that each measure of effectiveness be translated to an equivalent score.
d) A decision maker must consider issues such as implementation, schedules, financing, and legal and political matters.
e) When a project has been completed and has been in operation for sometime, a post evaluation can be useful means to examine the effectiveness of the results.
f) The usefulness of an evaluation procedure is its effectiveness in assisting decision makers to arrive at a solution that will best accomplish the intended goals.
g) The principal reasons why the rail system appears more attractive than the bus is because it provides al-day service is simpler to understand and use, and produces a higher quality of service.
h) Ranking and rating evaluation is an attractive approach because it can accommodate wide variety of criteria and can incorporate various viewpoints.

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