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Social cost impact assessment of pipeline infrastructure projects

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ABSTRACT

A key advantage of trenchless construction methods compared with traditional open-cut methods is their ability to install or rehabilitate underground utility systems with limited disruption to the surrounding built and natural environments. The equivalent monetary values of these disruptions are commonly called social costs. Social costs are often ignored by engineers or project managers during project planning and design phases, partially because they cannot be calculated using standard estimating methods. In recent years some approaches for estimating social costs were presented. Nevertheless, the cost data needed for validation of these estimating methods is lacking. Development of such social cost databases can be accomplished by compiling relevant information reported in various case histories. This paper identifies eight most important social cost categories, presents mathematical methods for calculating them, and summarizes the social cost impacts for two pipeline construction projects. The case histories are analyzed in order to identify trends for the various social cost categories. The effectiveness of the methods used to estimate these values is also discussed. These findings are valuable for pipeline infrastructure engineers making renewal technology selection decisions by providing a more accurate process for the assessment of social costs and impacts.

Introduction

Trenchless technology is a family of construction methods, materials, and equipment that can be used for the installation of new, or rehabilitation of existing, underground utility systems with minimal surface disruption and destruction resulting from the excavation (APWA, 1999). In contrast, open-cut methods can cause significant disruptions to traffic and adjacent commercial and industrial activities. The equivalent monetary values associated with these negative effects are commonly referred to as 'social costs' or 'external costs'. In this paper the term 'social costs' is used as a synonym for 'external costs'. Social costs are thus defined here as costs resulting from construction activities that are born by the community rather than by the contractual parties (Gilchrist and Allouche, 2005). Social costs can range from costs associated with adverse impacts on traffic conditions (e.g., delays and increased vehicle operating expenses), environmental costs (e.g., pollution), costs resulting from decreased safety (e.g., higher rate of traffic accidents and risk to pedestrians), accelerated deterioration of road surfaces (e.g., due to pavement cuts), lower business turnovers, decreased property values, and damage to existing utilities or adjacent foundations.

The presence of construction related social costs and the ability of trenchless methods to mitigate these costs are well recognized (Bottero and Peila, 2005; Boyce et al., 1998; Fea et al., 2000; Islam et al., 2013, 2014; Matthews, 2010; McKim, 1997; Sterling, 1994). However, designers and owners rarely take social costs into account during a construction project's planning, design and bid evaluation phases. One rationale is that social costs cannot be calculated using standard estimating methods (Xueqing et al., 2008). In recent years, several attempts have been made to introduce approaches and methodologies for predicting social costs associated with utility construction projects (Brady et al., 2001; CERIU, 2010; Gangavarapu and Najafi, 2004; Gilchrist and Allouche, 2005; Grunwald, 1997; Islam et al., 2014; Matthews and Allouche, 2010; Michielsen, 2005; Tighe et al., 1999). Nevertheless, unit cost data needed for the verification and validation of such prediction methods is lacking. This paper presents an overview of eight social cost categories. Two case histories of utility construction projects are introduced and discussed. Information provided for each case study includes: a) project background; b) reported social cost categories; and c) estimated monetary values for each category. The case histories are analyzed and compared in order to identify trends and derive typical cost values and cost ranges. Methods used to compute the various social cost values are also compared, and their effectiveness and viability are discussed.

Social cost categories

Eight social cost categories are considered in this paper. While other social cost categories could be relevant, the eight considered appear to be both common to many utility construction projects as

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well as suitable for quantitative evaluation in a reasonably systematic manner.

Travel delay

Utility construction work can cause significant traffic delay due to lane closures or complete road closures forcing detours. Pedestrians also can be forced to detour due to re-routing of public transportation services and blocked sidewalks. Brady et al. (2001) estimated the annual costs of traffic disruption arising from utility work in the U.K. alone to be £2 billion. Delay costs for traffic can be calculated using the following equation:

$$DC_t = VT * N_v * ITT * D_h \tag{1}$$

where DC_t is the delay costs for traffic [$/h]; VT is the value of time [$/h]; N_v is the number of vehicles [vehicles/h]; ITT is the increased travel time [h/vehicle]; and D_h is the project duration [h].

Increased travel time (ITT) or travel delays can be measured directly at the project site or can be calculated using established principles. For the case of partially obstructed roadways (i.e., ignoring detour delays), Tighe et al. (1999) defined user delays as both slowing delays caused by the reduced speed through the affected area and queuing delays due to congestion when traffic demands exceed roadway capacity. The Highway Capacity Manual provides calculation procedures for determining such delays (TRB, 2000). Selecting the most appropriate procedure for determining the anticipated delay requires knowledge of the roadway configuration and number of lane closures. A procedure for determining delays in a two-lane road, with one-lane closed down, and flag people at each end of the closed section, is presented below in detail for illustration purposes.

The normal capacity of the roadway is determined by considering the number of heavy vehicles traveling on that road:

$$NC = 1700/HV \tag{2}$$

where NC = normal capacity for two-lane road [vehicles/hour/lane]; 1700 = capacity of passenger cars per hour per lane in ideal conditions [cars/hour/lane]; and HV is the adjustment factor for heavy vehicles, computed by the following equation:

$$HV = 1/(1 + (F_{HV} * 0.5)) \tag{3}$$

where F_{HV} is the fraction of heavy vehicles in the vehicle stream.

Next, the reduced capacity of the roadway, RC [vehicles/hour/lane], is determined as follows:

$$RC = NC * (Green/Cycle) \tag{4}$$

Table 1
Green times and cycle lengths based on AADT.

AADT	Green time (s)	Cycle length (s)
<3500	100	400
3500–4000	150	500
4000–6500	250	700
6500–7000	300	800
7000–7500	350	900
7500–8000	400	1000
8000–8500	450	1100
8500–9000	500	1200
9000–9500	570	1340
9500–10,000	610	1420

where the values for green times (*Green*) and cycle times (*Cycles*) for a range of average annual daily traffic (AADT) values are listed in Table 1.

The hourly volumes for both peak and off-peak hours are computed next:

$$HV_P = AADT * k * 0.5 \tag{5a}$$

$$HV_{OP} = [(AADT-(HV_P * PH))/(24-PH)] * 0.5 \tag{5b}$$

where HV_P = peak hourly volume [vehicles/hour]; HV_{OP} = off-peak hourly volume [vehicles/hour]; k = area adjustment factor [0.1 for urban areas & 0.09 for rural areas]; PH = peak hours [hours]; and the constant of 0.5 is used to account for the lane which is closed down.

Finally, delays are calculated for both peak and off-peak hours as follows:

$$D_P = \left[\left((0.5 * Cycle) * \left((1-(Green/Cycle))^2\right)\right)/(1-(X_P * (Green/Cycle)))\right]/3600 \tag{6a}$$

$$D_{OP} = \left[\left((0.5 * Cycle) * \left((1-(Green/Cycle))^2\right)\right)/(1-(X_{OP} * (Green/Cycle)))\right]/3600 \tag{6b}$$

where D_P and D_{OP} are the delays during peak and off-peak hours respectively [hours]; $X_P = HV_P/RC$; $X_{OP} = HV_{OP}/RC$; and 3600 = conversion factor [seconds/hour].

The total delay is simply the summation of the peak and off-peak delays. This delay can then be used in Eq. (1) to calculate the cost due to traffic delays.

In the case of highly urbanized areas with extensive surface public transportation systems, delay costs for pedestrians could be a significant factor. These can be computed using the following expression:

$$DC_p = VT * N_p * ITT * D_h \tag{7}$$

where DC_p = delay costs for pedestrians [$]; N_p = number of pedestrians [person/h], VT = value of time [$/h]; ITT = increased travel time [h/person]; and D_h = project duration [h].

Vehicle operating costs

Longer travel distances and stop-and-go traffic result in higher vehicle operating costs. For example, 1000 speed changes from 80 km/h to 24 km/h and back to 80 km/h cause an additional fuel consumption of 55 l for light duty vehicles (Budhu and Iseley, 1994). Vehicle operating costs can be calculated using the following expression:

$$VOC = ITD * OCA * N_v * D_h \tag{8}$$

where VOC = vehicle operating costs [$]; ITD = increased travel distance [km]; OCA = operating cost allowance [$/(km vehicle)]; N_v = number of vehicles [vehicles/h]; and D_h = project duration [h].

Decreased road surface value

Open excavations can result in pavement deformations and asphalt cracking at the edges of the trench, which leads to an accelerated degradation of the pavement. Reduction in useful pavement life due to an open-cut excavation is estimated to be as high as 30% (Tighe et al., 2002). Kolator (1998) proposed the following expression for calculating the average decrease in the road surface value:

$$RSV = L_s * 110\,[\$/\mathrm{m}] \tag{9}$$