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Costs and benefits of Waste Soils removal

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Costs and benefits of Waste Soils removal

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Abstract

Piles of soil excavated from construction sites become a problem when they are left on site for several reasons. For example, they are exposed to wind and water erosion and constitute an environmental nuisance by disturbing the natural landscape. Thus, they create an external cost. In Israel, it is illegal to leave such piles after the project ends. The aim of this paper is to test the efficiency of this mandatory policy. We estimated the benefit of transferring such waste soil to designated landfills through Contingent Valuation (CV) which assesses people's willingness to pay for the removal of the nuisance. We then compared it to the removal cost. To estimate these costs we used linear programming to find the minimum cost of transporting the soil to a set of designated landfills. Our results indicate an annual net benefit of ILS 4.7 million (about USD 1.34 million). This translates into a Benefit-Cost-Ratio of 1.058, which is not significantly different from 1 based on the confidence interval for willingness to pay. Net benefit is also sensitive to assumptions regarding transportation cost.

Keywords: contingent valuation, excavated soil, transportation costs, Israel, cost-benefit analysis

JEL Classification: Q24, Q51, R14

Highlights:

- ✓ Piles of waste soil excavated from construction sites become an environmental nuisance when they are left on site. However, can be treated as a resource.
- ✓ Using a minimum cost model and Contingent Valuation methods, we perform a Cost Benefit Analysis of removing the waste soil to designated landfills.
- ✓ The net benefit is positive although not significantly different from zero, calling for further research to explore more promising alternatives.

1. Introduction

Infrastructure projects belong to a large and dynamic industry that provides processes for building new structures (Çelik et al. 2017). These projects are considered important for the growth of local and national economies (Osei 2013). They are also considered a measure of the quality of life and are standard indicators of life satisfaction (Damigos and Kaliampakos, 2003; Myers 2013; Sassi 2016).

The amount of waste soil accumulated in the European Union in 2014, due to the expansion of infrastructures, was estimated at $463x10^6$ tons (www.eurostat.com)[1]. It is estimated that in the near-

[1] Eurostat database, waste generation and treatments, last updated on 15.05.18, retrieved on 05.08.18.

future waste-soil amount will increase because of the rapid development of infrastructures due to population growth (Tanner et al., 2018)

Though infrastructure may improve people's quality of life, construction projects can also have adverse impacts on their surroundings (Ayalon et al. 2006; Dal Sasso et al. 2012; Einarsdóttir et al. 2019; Matthews et al. 2015; Neri and Sánchez 2010; Staunton et al. 2015). The environmental consequences of such projects can be significant. One such consequence is a change in landscape structure (Loures et al. 2015; Nijnik et al. 2009; Willis and Garrod 1993). Such environmental consequences are considered external costs and as such do not carry a direct market price. Nevertheless, they are considerable and may cause, without proper treatment, spatiotemporal land-use hazards (e.g. Aires et al. 2018). Therefore, land use impact assessment could not be understood in this broad sense without quantifying those impacts (Dal Sasso et al. 2012; Howley et al. 2012; Molina et al. 2016; Perminova et al. 2016; Ronchi et al. 2019; Xueqing et al. 2008). Decision-makers need this information to perform a Cost Benefit Analysis (CBA) at the planning stage of such projects (Chen et al. 2015; Dribek and Voltaire 2017; Song et al. 2015). Using Environmental Impact Assessment (EIA) is largely a descriptive analysis of the project, usually without monetary implications (Einarsdóttir et al. 2019). Therefore, a CBA is more convincing if a dollar value can be assigned to the aesthetic damage brought about by a project, allowing its incorporation into the accompanying economic analysis (Kapper 2004). Du Preeze et al. (2012) found significant Willingness to Pay (WTP) for the removal of Manganese Ore dumps and some oil tanks from the Port Elizabeth Harbour in South Africa. However, the study, as others mentioned above, strongly recommends comparing the benefits of nuisance removal to the cost of doing so. This is the main goal of this paper.

Soil and land issues call for CBA on various topics (Weiler et al. 2018; Zhang et al. 2019). Soil excavated from construction sites (waste soil, WS) is an example of a potential social cost. Most of the excavated material is deposited near the construction site, in moderate-height piles lacking mechanisms for stormwater management or erosion control (Fig. 1). Since the piles are considered temporary, no rehabilitation processes are taken, thus creating a local hazard due to rapid runoff, erosion and drainage problems (Foster et al. 1995). On a broader scale, without appropriate rehabilitation, it can alter landscape structure and stability, exposing the surrounding environment to rapid degradation, and therefore becoming an environmental nuisance (Evans 2000; Tanner et al. 2018). In fact, the environmental impacts of WS are a global problem. In the EU waste stream strategy plan (EC 2001), construction and demolition waste is considered one of the most crucial waste issues. However, in most places, globally, professional stakeholders and authorities are not forced to consider recycling WS or using it as a resource. The solid waste stream includes a wide range of materials, categorized into four major groups depending on their source (Symonds Group 1999): [1] *waste arising from the total, or partial, demolition of building and/or infrastructure*; [2] *Waste arising from construction of buildings and/or civil infrastructure*; [3] *Soil, rocks and vegetation arising from land leveling, excavation, civil works and/or general foundations;* [4] *Road planning and associated materials arising from road maintenance activities*. Of these, excavated WS (including sand, gravel, and clays) is a significant property in every construction site, and a substantial portion is considered non-reusable. Moreover, WS is the most rapidly growing component of solid waste due to the increasing global demand for mass transportation and urban infrastructure. Some of the WS is disposed of in landfills; some are used to fill mining sites or in civil engineering of reclamation sites, as landfill cover, to build earth embankments, or to add to or level out agricultural land (Magnusson et al. 2015). But many countries do not have the regulations, financial resources, or infrastructure to control WS properly

(Umar et al. 2017). In Israel, for example, the common practice is to refill other excavated areas (e.g., quarries and mines).

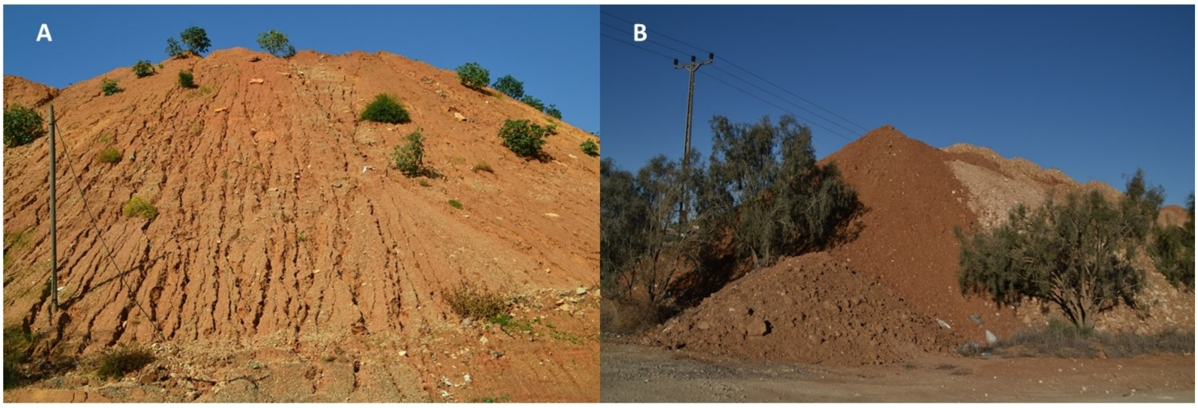

Figure 1: excavated soil piles. [A] A single-source eroded Sandy-loam pile; [B] multi-source untreated excavated pile

The external cost of accumulating WS causes a market failure since a construction firm has no incentive to prevent or remediate its negative impacts. To analyze any regulatory intervention, a CBA should be performed. Since the benefit of eliminating these WS piles is considered a non-market good, social cost–benefit analysis should quantify it monetarily. In the Netherlands, for example, CBA has an increasingly important role in the evaluation of so-called "integrated" hybrid infrastructures. Such projects strive to realize, for example, a combination of infrastructure among other development projects (Pappalardo et al., 2017). As developers of national as well as regional projects depend on public support, it is clear that the non-market values that affect the public should be taken into account in the analysis (Mouter et al. 2015; Sijtsma et al. 2013). A specific example of such a nuisance was analyzed by Navrud et al. (2008) for the issue of overhead transmission lines versus underground cables in Norway. They found that the social benefit of burying the cables is twice as large as the cost difference between the two options.

Estimating the cost of eliminating WS is complicated because there are many potential landfills and construction sites, so it becomes a minimum transportation cost problem. Here, we use a minimum transportation model to estimate the lowest cost to spread WS among designated sites.

The aim of this paper is thus to analyze the idea of moving the WS piles by performing a CBA. To our understanding, there is no such paper about this topic so the work is innovative in that respect and can shed some light on similar future analyses in other places. This is true for the specific issue dealt with in this paper and for any other environmental policy that requires a comparison between the benefit of the proposed policy and its cost.

Here we do that by using linear programming to find the minimum cost of transferring a given amount of WS to designated landfills. We then compare that cost to the benefit of eliminating the WS piles. The benefit is estimated with contingent valuation (CV), in which a questionnaire is used to ask a representative sample of people about their willingness to pay (WTP) for such a program. We have seen no other study that dealt with WS using social CBA. We contribute to the literature by considering a case in Israel, which should be further analyzed in different aspects beyond its landscape nuisance.

The paper continues as follows. The next section describes the CV methodology and the minimum transport cost model. Section 3 describes the survey used and the transportation model. Section 4 presents the results while section 5 discusses some policy issues. Section 6 concludes the paper.

2. Methodology

This section describes the two models used in this research: the contingent valuation model that measures the value of a non-market good to consumers, and the minimum cost model that identified the cheapest (in terms of transportation costs) distribution of waste-soil from different construction sites to different landfills.

In situations where no market exists for a particular good, non-market valuation methods are required to estimate the economic value, for example of environmental public good provision (Buckley et al. 2016). People may be willing to pay for restoration programs because they derive aesthetic and other services from the landscape (Wilson et al. 2019). Such values can be use-values—for example, travelers might appreciate not seeing piles of construction debris on their trips—or non-use values—for example, even people who never visit a particular landscape might be glad it’s there (Champ et al. 2003).

2.1 Contingent valuation method

The value of goods is measured by their importance to consumers, and this importance is determined by their preferences (Kokoye et al. 2018). Preferences are evaluated by the consumer’s WTP for that good. When a market price is not available, the value needs to be indicated by the consumer. There are several techniques that are used in the absence of a real market to ascertain people’s WTP for the good.

Such methods of valuation include stated and revealed preferences. Revealed preference methods use people’s actual behavior in real markets, rather than their conjectured behavior in hypothetical markets. The revealed preference method uses the actual behavior of individuals with respect to a given non-market good (e.g., visit frequency to a site). The stated preference method estimates the monetary value of a good by asking people how much they are willing to pay for it to be provided, or not eliminated (Boxall et al. 1996). In this study, the stated preference method was used. The main reason for choosing this method is that common revealed preference methods such as travel costs are not applicable to this case. One would have to measure the frequency of visits to sites with and without WS piles. But such piles are not located at recreational sites but at infrastructure projects along roads, railways, and so on—so the difference in consumer preferences cannot be leveraged.

The two major classes of stated preference elicitation techniques associated with the provision of environmental public goods are CV and choice experiments. Choice experiments tend to deal more explicitly with how non-market values relate to individual and site attributes that make up the environmental good. CV takes a more general approach by focusing on the value of moving from the status quo to an alternative situation of the good (Hynes et al. 2011). Thus, CV seems best suited to valuing the overall policy package and choice experiments to valuing specific attributes of that policy.

The CV is a survey-based methodology that simulates a market in which respondents are exposed to information on new goods and how it affects their WTP. This method was first used by Davis (1963), who designed it to assess the economic value of recreational forests in Maine. The CV is considered suitable for hypothetical scenarios and is thus more flexible than other techniques (Venkatachalam 2004). CV is a major tool to estimate preferences regarding landscape structure changes (Molina et al. 2016).

Questions about WTP can be used to estimate the total economic value of a program. They can also split this overall value into categories that point to different motivations: use value, option value, bequest value and existence value. The first two relate to the use or option to use the resource in an active way, while the last two relate to non-use motives in either allowing future generations to enjoy the resource or just “knowing it’s there” (e.g., Wattage and Mardle 2008).

The reliability and validity of CV have been questioned (Diamond and Hausman, 1994). However, as pointed out by numerous studies, it has emerged as a valid tool for estimating the benefits of non-market goods (e.g., Loomis 2011; Boyle 2003). This is especially true when respondents care about the proposed program and believe their responses have a positive probability of influencing the final outcome. Carson and Groves (2007) call this “incentive compatibility.”

In studies of natural resources, CV studies generally derive values by eliciting respondents’ WTP to prevent damage to natural resources or to restore damaged natural resources (Endalew et al. 2018). To elicit more reliable responses, researchers have developed various methods of asking evaluative questions, including open-ended questions, payment cards, and dichotomous choice formats. These three main CV response formats have their own strengths and weaknesses. While an open-ended format often results in overestimating WTP, a dichotomous-choice WTP question obtains only a limited amount of information from each respondent, since it asks only whether they are WTP a certain amount. The payment card (PC) method is a question format in which the respondents are asked to pick a WTP from a list of values on a card provided during the interview.

The PC format is useful as it provides explicit information per respondent (Boyle 2003). This is not the case in the discrete choice format, in which respondents answer yes or no to a given bid. The PC method is also simpler than the open-ended format, so a broader range of responses can be obtained (Bateman et al. 2002; Liou 2015).

2.1.1 Payment Card Models

In the PC format, each respondent is shown a list of payment amounts (including zero), and asked to circle the one representing their maximum WTP for the good in question. An issue concerning PC surveys was pointed out by Cameron and Huppert (1989), where the PC data were analyzed by modeling the intervals bounded by the bid amount the respondent circled and the next higher amount shown on the PC. Since the respondent *would* pay the circled amount, but *would not* pay the higher one, their true WTP presumably lies between the two.

The true WTP of respondent *i*, WTP_i^*, is a latent variable, given as

$$WTP_i^* = \beta X_i + \varepsilon_i \tag{1}$$

where β is a vector of coefficients, *X* is a vector of the potential determinants of respondents’ WTP, and ε is an error term.

The probability that respondent *i* chooses the range $[L_i, U_i]$ is

$$Pr\ (L_i \leq WTP^* \leq U_i) = Pr\ (L_i \leq \beta X_i + \varepsilon_i \ \leq U_i) = Pr\ (L_i - \beta X_i \leq \varepsilon_i \leq U_i - \beta X_i\ ) \quad (2)$$

Assuming that ε follows a normal distribution (0, σ^2), equation (2) can be written as

$$Pr\ (L_i \leq WTP^* \leq U_i) = \left(\Phi\left(\frac{U_i - \beta X_i}{\sigma}\right) - \Phi\left(\frac{L_i - \beta X_i}{\sigma}\right)\right) \quad (3)$$

Where $\Phi(\cdot)$ is the standard normal cumulative distribution function. Equation (3) reflects the contribution to the likelihood function of an interval regression model for respondent *i*. The likelihood function of the interval model for the entire sample is calculated by multiplying the individual contributions to the likelihood function for all individuals in the sample. The likelihood function is maximized to obtain estimates of β and σ.

2.2 Minimum cost model

In minimum cost models we aim to minimize total transportation costs subject to two types of constraints. Constraints of the first type force the total removal of WS from each infrustructure site. Constraints of the second type do not allow the transfer of more WS than can fit in the designated landfill.

Formally, the cost minimization problem is specified as:

$$\text{Min. TC} = \sum C_{i,j} \times X_{i,j} \qquad \forall\ i = 1, \dots, I \quad \text{and} \quad \forall\ j = 1, \dots, J \quad (4)$$

subject to

Removal constraints: $\sum X_{i,j} \geq DS_i \quad \forall\ i=1, \dots, I$ (5)

Site capacity constraints: $\sum X_{i,j} \leq LC_j \quad \forall\ j=1, \dots, J$ (6)

where

TC = total (transportation) cost

i = index of infrastructure site

j = index of landfill site

DS_i = soil supply from site *i*

LC_j = landfill capacity of site *j*

$C_{i,j}$ = transportation cost from site *i* to site *j*

$X_{i,j}$ = amount of soil transported from site *i* to site *j*.

The objective function (4) is minimized the transportation cost of moving surplus waste between infrastructure sites and landfills, over the values of Xi,j subject to two types of constraints. The removal constraints (5) mean that all and the surplus must be removed. The capacity constraints (6) mean that the total material that arrives at a specific landfill site cannot exceed that site's capacity.

3. Survey design, questionnaire, and variable measurement

3.1 Survey design

A consumer survey was conducted in various public places in Israel to collect the required data. This includes train stations, shopping malls and town squares. We than compared the descriptive statistics to the national statistics to assure representativity. Our target population was the entire Israeli population, and care was taken to make the sample representative of the general population. Altogether, 290 questionnaires were completed, and 246 were finally used.

We used a face-to-face survey, which is recommended for CV studies due to its flexibility, high response rate and better control of the sample, as compared to other data collection methods (Pearce et al. 2002). Before the formal survey, a pilot survey was carried out to check the logic of the bidding process, the relevance of the proposed bid values, and the measurement of the independent variables in the model.

3.2 Questionnaire, variables, and survey results

The questionnaire began with a brief introduction to the issue, with pictures of WS piles. Following this introduction, there were four questions on the respondent's experience: how often the respondent saw WS piles, where they saw them, the mode of transport they were using at the time, and how much of a nuisance they found them to be.

Before asking about WTP, we made sure respondents read two "cheap talk" statements and caution to avoid protest bids (Cummings and Taylor, 1999; Chen et al. 2018):

> *We ask you to be sincere and answer like as if it was a real decision, although it is not. We want you to consider the trade-off in protecting the environment, which means less money available for other things that are also important.*
>
> *On the other hand, we would like you to remember that the program will not be implemented unless most Israeli taxpayers agree to contribute to this fund.*
>
> *Finally, we would like to stress that the question we are asking is solely about the value of restoration. Try to ignore the issue of whom the blame should fall on, because this issue is to be solved in another arena.*

We then moved to the bidding process. We asked:

> *Suppose a public fund is generated whose sole purpose is to manage the soil pile issue. How much are you WTP to resolve this problem based on the information you have received so far? Please indicate your maximum WTP (as a lump sum amount) on this card:*

0	15	30	45	60	75	90	105	120	135	150	More (specify)

The third section dealt with the reasons for payment. There were seven reasons, of which respondents could mark one or more. Four were used to estimate the relative weights of the four types of value: use, option, bequest and existence. The other three dealt mainly with reasons for zero WTP. Two reasons were considered legitimate: not being able to pay; and considering the issue unimportant. But if the respondents declared that payment was not their responsibility (and marked zero as their WTP), it was considered a protest bid and they were left out of the survey analysis. The reasons are summarized in Table 1.

Table 1: Reasons for WTP

Reason	Interpretation
I feel responsible for restoring the landscape after damage by infrastructure projects.	Existence value
I would like to see the undisturbed landscape while driving.	Use value
The issue is not important to me to spend money on.	Legitimate zero response
I am willing to pay so my offspring will have the option of enjoying an undisturbed landscape.	Bequest value
It is not my responsibility to pay for such issues.	Protest bid
I would like to retain the option to enjoy the undisturbed landscape, although at the moment I do not observe it on my driving routes.	Option value
I cannot afford to spend any money on this issue.	Legitimate zero response

The fourth section included socio-demographic questions to test how economic theory is embodied in the responses. The variables were gender, age, number of people in the household, place of origin, education, membership in a green organization (one which acts to protect and conserve the environment), and income (See Table 2 for a list of survey variables in addition to those listed in Table 1).

Table 2: Variable descriptions

Type of question	Variable	Definition	Scale
Opinion	Observation frequency	More than 5 per week = 5 Never = 1	[1-5]
	How much do they disturb you	I see them as a major disturbance =5 No difference to me = 1	[1-5]
	Driving intensity	Likert scale between 1 to 5	[1-5]
Payment	Willingness to pay	ILS 0-150 or more	ILS 15 increments
Socio-demographic	Gender	Female=1	[0-1]
	Age		Cont.
	Persons per household		Cont.
	Education	4 levels	[1-4]
	Green organization	Membership=1	[0-1]
	Income	5 levels	[1-5]

4. Results

4.1 Transferring WS

4.1.1 Transportation cost

We use a mean estimate of two transport schedules.[2] The first is based on a daily schedule of a truck, in which a full working day is assumed. The second approach estimates the cost per trip, which has a higher cost per kilometer. In both cases a truck can load 11 tonnes of WS material. The cost per kilometer is ILS 10.7 and ILS 6.8 for daily and individual trips, respectively. Taking the average and dividing by 11 tonnes, we get ILS 0.8 per cubic meter of WS.

4.1.2 Cost minimization

There are 36 infrastructure constraints and 15 landfill constraints (51 total). In addition there are 560 decision variables (35 × 16). The LINDO package was used to find an optimal solution. The minimum-cost solution, ILS 80.9 million, was found after 63 iterations. Of the 560 decision variables, 48 are non-zero. Figure 2 presents the results in such a way that the intersection of horizontal and vertical values is a non-zero variable and the amount of the WS being transported is indicated by the size of the circle.[3]

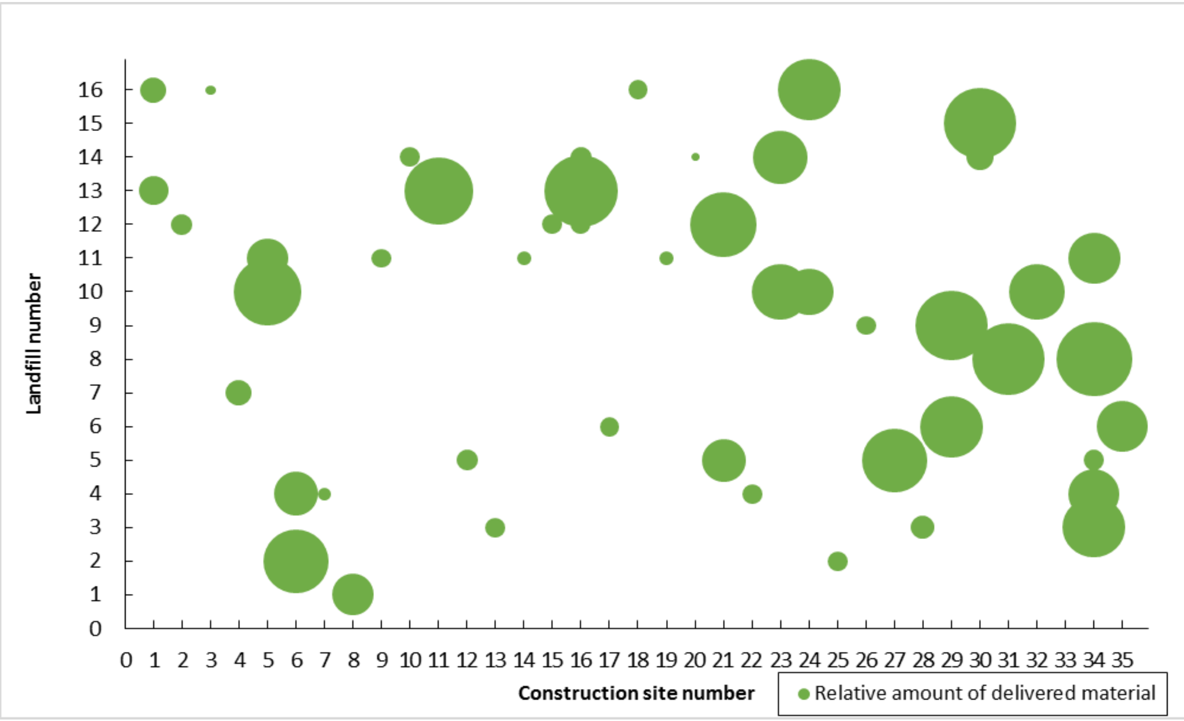

Figure 2: Transport of WS from infrastructure i (horizontal axis) to the landfill site j (vertical axis). The circle size indicates the transported amount.

[2] Estimates based on data from the Israeli Heavy Transport Council.
[3] 1 ILS = USD 0.29

The 48 non-zero variables are the ones that transport WS surplus between two relatively close sites. Sites are arranged from the north to the south of Israel. Therefore, the transportation cost should be lower when the combination of the site and landfill is closer to a hypothetical 45° line. But there are many combinations far from the line, indicating that the optimal solution is a non-trivial distribution from supply node (infrastructure site) to demand node (landfill).

One reason is the capacity of the designated landfills. To demonstrate this we consider the scarcity of space by providing the shadow price for each of the 16 landfill sites (Table 3). These Shadow prices appear in for each site that was filled up and indicate the value of an additional cubic meter of available space.

Table 3: Shadow prices for landfill sites

Landfill site	Shadow price (ILS/m^3)
1	0.00
2	9.00
3	9.30
4	0.30
5	24.30
6	15.10
7	0.00
8	62.30
9	43.10
10	98.80
11	72.60
12	9.70
13	73.10
14	64.40
15	84.40
16	20.30

Only 2 of the 16 landfill sites have a zero shadow price. This means that they are not full. The shadow price for the other 14 sites varies from ILS 0.3 to ILS 98.8 per cubic meter. Another reason for the non-trivial distribution of WS is the reduced cost, which can be thought of as the shadow price of one cubic meter at a given construction site. This is the change in the value of the objective function of one more (or less) cubic meter of WS at a construction site (Figure 3).

The range is between zero and ILS 220.3, with a mean of ILS 75.[4] It is clear that there is no correlation between the size of the site and its reduced cost. The reason is that we have to account for not only the amount of soil waste but also the distance to the different designated landfills.[5]

[4] Zero can occur either because there is an alternative solution or through rounding.
[5] Two sites have a zero reduced cost. In an optimal solution they were to be left as they are and not removed. However, our analysis is not seeking for an optimal solution but for an answer for the plan as a whole (removing all piles).

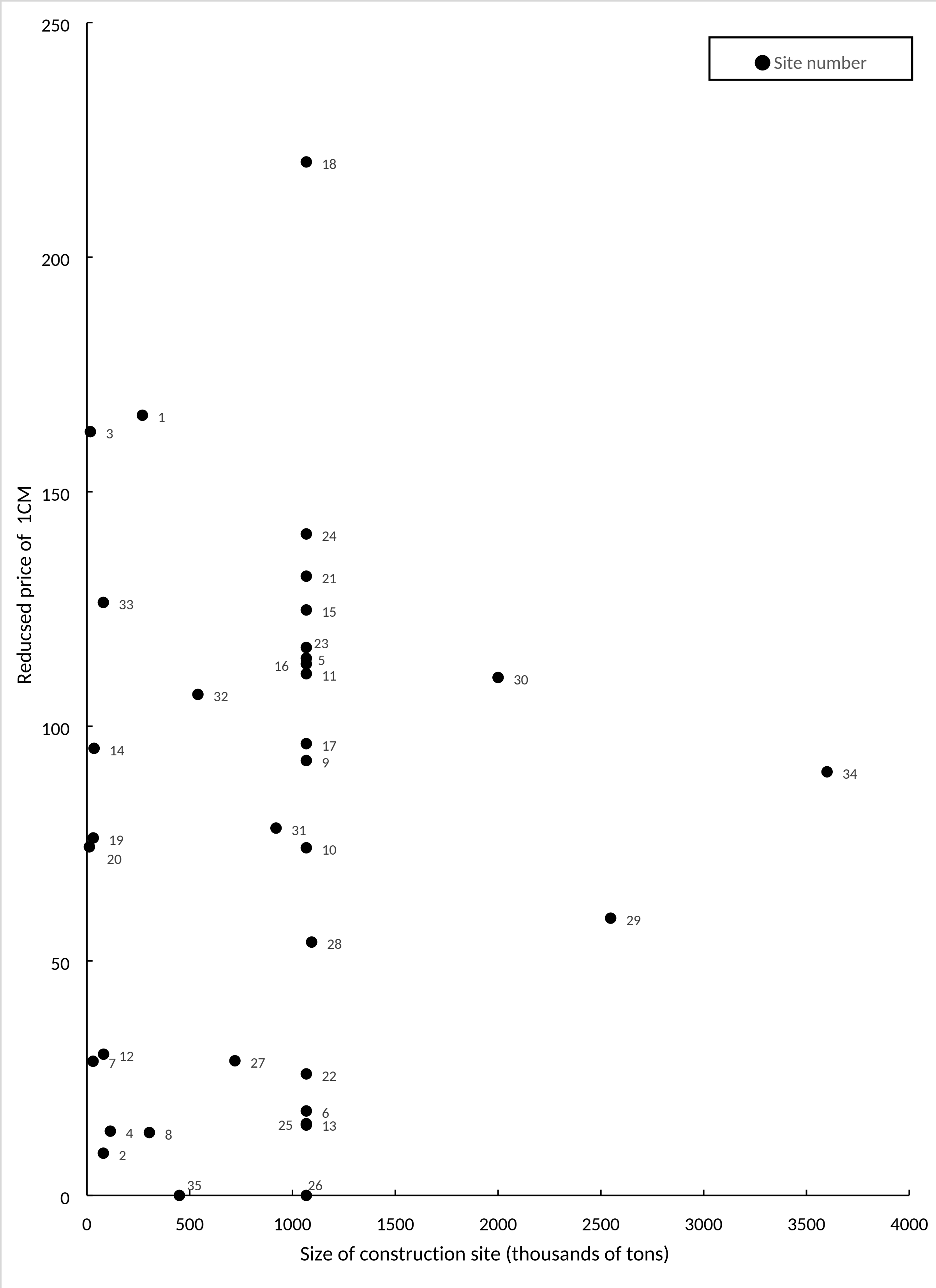

Figure 3: Reduced cost (shadow price, in ILS) of 1 m^3 at different construction sites, ordered by size

4.2 Non-market valuation of removing soil piles

4.2.1 Characteristics of sample consumers and their WTP

Of the 290 respondents, 168 (57.9%) were willing to donate funds to the restoration scenario. Of those unwilling to donate, 78 (26.9%) were classed as true zero WTP, while 44 (15.2%) were classed as protest bids . This latter figure is somewhat larger than the 10.8% found by Navrud et al. (2008) with respect to transmission cables. Protesters were not included in the WTP models because they do not express a true value. Thus, only 246 questionnaires were analyzed. After deleting the protest respondents, the share of respondents WTP something increased to 69%, a bit less than the 76.8% found by Navrud et al. (2008). Table 4 presents the background information of the sample survey.

Table 4: Background information on respondents and their households

Features	Mean	Std. dev.	Median
Observation frequency [0-4]	2.02	1.42	2
Disturbance degree [1-5]	2.45	1.01	2
Driving intensity [1-5]	3.23	0.98	3
Income [1-5]	3.04	0.90	3
Education [1-4]	2.17	0.90	2
Persons per houshold	3.69	2.01	4
Age[6]	32.5	9.37	29
Origin (Israel = 0)	0.17	0.37	0
Gender (female = 1)	0.46	0.50	0
Green (member = 1)	0.03	0.18	0

Observation frequency, disturbance degree, income, and education are all around the mean level of the Likert scale. Mean levels of the explanatory variables were compared to the national statistics in Israel (CBS, 2018). Mean number of persons per household is 3.69 (it is 3.6 in Israel as a whole). Mean age is 32.5 (31 in Israel as a whole). 46% of the respondents are females (50.4% in Israel as a whole). 83% were Israeli-born (79% in Israel as a whole); Green membership is declared by 3% of the respondents; and finally, driving intensity was around the mean value.

The mean and the median of predicted WTP were used to derive the average economic value respondents give to removing the WS piles. Table 5 reports the results for each ILS 15 range.

We find the mean WTP to remove WS piles to be ILS 34.1 per household (± ILS 7.7, 95% C.I.). The median was ILS 20.0, with standard deviation ILS 42. According to national statistics, there are 2.51 million households in Israel as of 2017. (CBS, 2018). Thus, we estimate the total value of removing all soil piles at ILS 85.6 million.

[6] Only adults over 18 years of age were surveyed.

Table 5: Distribution of WTP

Range (ILS)	Share of respondents (%)
0	31
1-15	16
16-30	15
31-45	4
46-60	15
61-75	0
76-90	6
91-105	7
106-120	3
121-135	0
136-150	3

Among the different motivations, use value is the most reported (33%), followed by existence value (27%), option value (22%), and bequest value (16%). If we combine use and option value on one side and existence and bequest value on the other side, we get 55% and 45%, respectively.

4.2.2 Econometric results

Table 6 presents the results of the interval regression to analyze the predictors of WTP.

Table 6: Result of interval regression on WTP (n = 246)

Variable	Coefficient	S.D.
Disturbance level	−18.5***	3.88
Visual frequency	−2.51	1.73
Gender (female = 1)	0.898	0.62
Age	0.295	0.35
Persons per household	3.26***	1.60
Origin (Israel = 1)	20.029***	8.63
Education	4.565	3.79
Green	48.8***	17.5
Income	3.72	3.79
Road use	9.584***	3.34
Constant	51.17***	22.53
Log-likelihood	−399.431	
Prob. > $\chi 2$	0.00	

*Note: Values in parentheses denote standard errors; *p < 0.10, *p < 0.05, ***p < 0.01.*

Four variables significantly affect consumers' WTP, three of them in the expected direction. The exception is the disturbance variable which is negative meaning subjects with a higher stated disturbance level are WTP less than those who care less. This is counter-intuitive. The number of persons living in a given household positively affects WTP (recall that the WTP is per household). Membership in a green organization has the most positive impact on the WTP, in a positive direction. Finally, road use intensity also has a positive effect. Neither income nor education has a significant effect.

5. Discussion

In our survey, education did not influence WTP to remove soil piles. This is consistent with some international studies (e.g., Batte et al. 2007; Navrud et al. 2008) but contradicts others (e.g., Du Preexe et al. 2012; Hai et al. 2013), which reported a significant positive effect of education on WTP. Also, income did not affect WTP in our survey. This contradicts other studies (e.g. Challcharoenwattana and Pharino 2016; Chen et al. 2018; Du Preeze et al. 2012; Green, 2018; Howley et al. 2012). Nor was the coefficient of age statistically significant, though one might think that older people are WTP more because of better familiarity with the topic (e.g., Song et al. 2012; Wiser 2007). However, our finding regarding green organization membership is consistent with Connelly et al. (2002), and Green (2018), who found that respondents had greater WTP for restoration activities if they were members of a green organization.

Among the awareness variables, it is interesting to note that visual frequency did not have a significant effect on WTP. Level of disturbance had a negative effect which is contrary to what one would expect. Driving intensity did affect WTP in the expected direction. Thus it seems that the level of nuisance is less important than the number of WS piles seen per week. Frequent drivers do care about the issue more than others, probably because they spend more time on the road and so hence are affected more by landscape nuisances.

To assess the efficiency of the program to dispose of the soil piles in designated landfills, we should compare benefits to costs. We use three values for benefits and three for costs. For the benefits we use the mean WTP, as well as the two values (low and high) that form the 95% confidence interval (That is ILS 34.1± ILS 7.7). For the costs we use the estimates for the mean cost of daily truck per CM as was specified in the results section, 0.8 per CM. For the sensitivity analysis, we also use the cost of daily truck use (0.62 per CM) and the cost designated trips (0.98 per CM). The resulting values are in (Table 7).

Our mean scenario has a positive net benefit of ILS 4.7 million (center of the table). However, in three of the nine scenarios, the net benefit is negative. When the transportation cost is high (designated trips), two out of three possible benefits options yield a negative net benefit. The net benefit is also negative when the transportation cost is at the mean but the benefit takes the lowest value. Concentrating on the mean value for transportation cost, we can conclude that the net benefit is not significantly different from zero [-12.7; 24.0] with a confidence interval of 95%..

Table 7: Total Net benefit (ILS millions) of different scenarios*

Benefit (ILS per household) / Cost (ILS per CM)	Low (26.4)	Mean (ILS 34.1)	High (41.8)
Low (0.62)	4.6	23.9	43.2
Mean (0.8)	−12.7	**4.7**	24.0
High (0.98)	−33.8	−14.5	4.8

* Inner number besides the base case scenario were calculated as follow: Total Cost was calculated by multipliying the ratio of the scenario (high or low cost) to the mean value which is 80.9 million ILS. Total Benefits were calculated by the high/low values (41.8 and 26.4 mrespectively) based on the C.I. and multiplied by 2.51 million households. Net benefit is the difference between the total Benefit and total cost.

Usually, studies concentrate on the benefit side, but for a CBA, we have to compare costs and benefits. The net results here are not as promising as in other studies that used both costs and benefits to reach a conclusion (e.g., Becker et al. 2009; Chen et al. 2018).

Variables affecting the sign of the net benefit can be found on both sides, benefits and costs. The removal cost can be affected by fuel and labor costs. The benefit of removal can be affected by the number of people driving along the roads and their WTP that may change over time due to changes in their income and environmental preferences (e.g., Hökby and Söderqvist, 2003). Finally, the external cost of transportation is another factor that may reduce the net benefit of the analysis. Since there is no known way to affect the WTP, at least in the short run, we are left with the cost side of the equation. Here, the government might have a role in nudging the infrastructure industry and transport companies to use trucks on a daily basis rather than for designated trips.

Another possible solution is to spread the soil surplus among nearby farmland. The average distance between a farm and a construction site is about 10 km. That is ILS 8 per drive. Looking at the reduced cost (the shadow price) of the infrastructure sites, we can observe that only two sites (26 and 35) have a lower shadow price than ILS 8. The average shadow price for a construction site is ILS 75. Hence, there is a cost-saving potential of ILS 67 (=75−8) per cubic meter, for the average construction site. In other words, diverting a cubic meter of soil from a designated landfill to a designated farm would save 89% of the transport costs, on average. Repeating the CBA with this new estimate, all nine scenarios have a positive net benefit, ranging from ILS 57.2 million to ILS 87.6 million. This, in turn, allows the transport mode to become entirely trip designated of course. The above calculation is a preliminary calculation but shows the potential for such a solution.

In a companion project (Argaman et al. 2018), a field experiment was conducted to examine the possible impacts of using WS on farmland. The effects of WS implementation on yield and soil quality were insignificant, implying that we cannot reject the hypothesis that the effects on yield and soil quality are negligible. This result supports the alternative of offering WS to nearby farmland as a resource rather than transporting it to remote landfills. Of course, we have to consider the cost of spreading, but this is estimated at ILS 3–4 per cubic meter, so it is not going to change the conclusion that spreading surplus soil on nearby farmland is probably a better idea than transporting it to more remote landfills.

6. Conclusions

The concern about the WS piles that accumulate during infrastructure projects is based on soil erosion as well as negative environmental impacts on the landscape. We consider a program that moves this excavated soil into landfills. The cost is measured in terms of transporting the soil from a given infrastructure site to a given designated landfill. This is measured by applying a linear programming model that minimizes transportation costs. Benefits, on the other hand, are estimated via CV. The CV used here was based on the PC format, which was econometrically analyzed by interval regression to identify the determinants of WTP for WS pile removal.

To find the net benefit we subtract the costs from the benefits under three different levels of each, for a total of nine net-benefit options. The central estimate is ILS 4.7 million, which translates into a Benefit-Cost-Ratio of 1.058. Based on the confidence interval for the WTP estimate and the different assumptions about the transportation costs, it is not significantly different from zero. Thus, the cost of transportation is the major barrier for the current policy to be socially beneficial. Where trips are more site-designated, the cost per cubic meter increases, reducing the overall net benefit.

With regard to future pathways for removing such piles in an economically justified way, we suggest looking closer at the possibility of absorbing WS (of appropriate quality) on nearby agricultural land, which often faces long-term soil degradation due to intensive farming. Thus, we call for further research on soil absorption by agricultural farms.

Our results highlight the importance of mitigating and minimizing waste beforehand while preliminary geospatial analysis of sink and sources will enable appropriate usage of transportation milage. Implementation within nearby agricultural fields utilizes these WS as a resource while reducing further environmental pressure as well as transportation costs to landfills.

Currently, stakeholder and decision-makers' awareness is a limiting factor. However, the long-term benefit-cost ratio implies that the multi-year accumulation of cost reduction per project is significant, whereas usage of WS as an agronomical resource will dramatically reduce the aforementioned.

Mouter et al. (2013) indicate that spatial planners and economists are in dispute with respect to the use of Cost Benefit Analysis of spatial infrastructure projects. Thus, instead of dealing with the pros and cons of the project, the debate is on the pros and cons of the process. We think that Cost Benefit Analysis can and should provide a benchmark to which policy makers can use as a crystal ball. Thus, even if they choose not to adopt the results, the opportunity cost should be a derived result of any action taken.

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