Benchmarking Infrastructure Costs: A Case of Road and Water Basket of Locally-Obtained Commodities (BLOC)

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Abstract

Although understanding drivers of infrastructure cost is an important part of cost management, data on costs are hard to obtain. Most importantly, cross-country comparisons of infrastructure costs are difficult to collect due to heterogeneity in infrastructure types and differences in country contexts. By standardizing input quantities and qualities of a road and a water infrastructure as well as accounting for currency variations, this paper documents a methodology to create a cross-city measure of infrastructure costs. Based on this benchmarking methodology, the derived cost differentials between pilot cities are attributable to factors other than quality, quantity, and the exchange rate.

Keywords: infrastructure costs; basket of locally-obtained commodities (BLOC)

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1 Introduction

Managing infrastructure construction costs is an important aspect to not only bring about improved economic returns to infrastructure investment (McKinsey Global Institute, 2013), but also send clear signals to investors on good governance and investment potentials. A key aspect of managing infrastructure costs is understanding the drivers of cost. However, internationally comparable infrastructure construction cost data are hard to come by. This makes it more difficult to have a robust understanding of cost drivers, differentials across locations, and possible policy measures as well as management practices to mitigate against high infrastructure costs. Broadly, there are three sets of challenges:

- Firstly, infrastructure projects are heterogeneous. Even for road infrastructure, they can range from country roads to interstate highways, and some could include difficult engineering features like tunnelling and flyovers. Water infrastructure likewise can be broadly defined: from sewage treatment plants to flood prevention systems. Some may also include water-based transportation infrastructure (e.g., canals). These would require different types of technologies and inputs to construct. Even within the realm of water treatment plants, different processes and different technologies are used.

- Secondly, country conditions are often also highly diverse. There are differences in local geographic conditions. These differences are further exacerbated by differences in regulations, market power of infrastructure developers (and also the market power of various suppliers of raw materials), and other institutional factors including governance. These can all affect the cost structures of infrastructure construction.

- Finally, there is a lack of internationally comparable prices that can better reflect underlying cost structures rather than just currency fluctuations. For example, a country may see its currency devalue by 30 percent against the United States dollar (USD). Comparing infrastructure costs across in USD (or any other currency) can become very misleading because of varying degrees of pass-through. Hence, there is a need to find a comparable price that controls for currency fluctuations.

Some attempts, however, have been made in recent past to analyze the drivers of infrastructure construction costs using country-specific datasets. For example, (Liscow & Brooks, 2019) found that infrastructure costs had been driven by rising incomes and housing by using data from United States Interstate highway system. Similarly, (Swei, 2018) analyzed construction costs, compensation, productivity and the price changes for inputs, and showed that Baumol's cost disease, a phenomenon where labor compensation growth outpaced productivity gains, was present in the construction sector. These papers, however, are rather limited in scope, focusing on one country (often developed economies due to availability of data), and do not allow for cross-country comparisons.

Nevertheless, suitable statistical methods can be set to account for each set of challenges. This paper documents a broad methodology for cost comparison, and then applies it to a road and a water infrastructure. The methodology is summarized as follows.

2 Methodology

2.1 Setting an Infrastructure Archetype

For each of the infrastructure categories, an infrastructure project type (an “archetype”) was chosen as the basis for comparing construction costs across locations. This archetype was selected to be as representative and as similar across comparator countries as possible. A highly representative type provides the best basis for analyzing the drivers of cost across countries. In particular, where the quality of a particular piece of infrastructure varies across locations, differences in cost may reflect a country’s choice to go with a high or low-quality option, rather than cost drivers that need to be managed. Moreover, it is important for costs not to be influenced too much by factors that are mostly beyond human control, such as topography; otherwise, comparative analysis may highlight these factors as the main drivers of cost, which would not be of much use to policymakers or the industry, since they cannot use these levers to bring down costs.

Having selected the infrastructure archetype, construction costs for each location were gathered through either known contract costs or detailed interviews with engineering consultants.

2.2 Creating a Basket of Locally-Obtained Commodities (BLOC)

With a standard infrastructure archetype, the next step was to identify the most commonly used combination of labor (L), materials (M) and plant and machinery (P) inputs. There can be many inputs that go into the construction process of the infrastructure. To make the data collection process more manageable, only the top 10 inputs were tracked.[1] A careful study of the Bill of Quantities (BoQ) across various projects was required to get a good sense of the top 10 inputs. Ideally, these inputs are sourced locally so that their cost is not affected by the exchange rate.[2,3] In both the road and water benchmarking exercises, Istanbul (Turkey) was chosen as the base city (the reasons for this are explained later in the paper). Its basket (quantity of each input constituents) of the selected top 10 inputs was used as the standard basket.

Having decided on the standard basket, detailed data on each item was then obtained for each of the locations in the benchmarking exercise. For example, if 100 hours of surveyor services were part of the standard basket, the cost of this (in local currency terms) would be obtained for each of the locations in this benchmarking exercise. Data collection, which is explained in detail in a subsequent section, extends to the rest of the items in the standard basket. Having done so for all the items in the standard basket, the basket price (for each location) could be derived through the appropriate aggregation. For example, it may cost RMB100,000 to obtain this standard basket in Shanghai (China), but TRY150,000 to obtain

[1] The top 10 inputs are based on expert assessment of the 10 most used inputs to construct a specific infrastructure.
[2] The exchange rate is a contributor to cost that may be beyond the control of those seeking to manage infrastructure costs; moreover, where the exchange rate is a significant contributor to estimated construction costs, exchange rate fluctuations can make it appear as though construction costs have changed, even if conditions on the ground have not changed, which may be misleading.
[3] By locally sourced, it means that the inputs are purchased in the local market in local currency, even if the input or part of the input is imported. It does not mean that all inputs have to be locally produced.

this in Istanbul (Turkey). This gives the basket of locally obtained commodities (or BLOC), priced in their respective local currency.

An index capturing road infrastructure costs was defined as the *roadBLOC* index, while water infrastructure costs were captured in the *waterBLOC* index. These respective indices follow a purchasing-power-parity (PPP) approach based on construction-specific data expressed in local currency—see the *citiBLOC* index developed by (Langston, 2019) (Langston, 2016) (Langston, 2014). Further details on how these indices are constructed are given in Sections 3.1 (for road) and 3.2 (for water).

2.3 Adjusting for Differences in Local Input Prices

In absolute terms, a city may be considered expensive because it has high construction contract prices; however, its costs may be lower after adjusting for prices of the inputs used in infrastructure construction (PPP effects).[4] If one can adjust for differences in the cost of inputs, there can be a comparison of the cost of the infrastructure construction and project management itself across locations, separated from the cost of inputs. This allows a comparison of the cost-efficiency of infrastructure construction across locations, creating an evidence base for analysis of the drivers of cost or efficiency in infrastructure construction.[5] Similarly, the measure of infrastructure construction costs needs to be independent of differences in real exchange rates across locations (i.e. the measure should be "currency-agnostic").[6]

Both objectives[7] could be achieved if we deflate the construction contract price of the archetype in each location (in local currency) by the price of their respective standard baskets, also in local currency. This gives the benchmark for infrastructure costs—the contract price of a project archetype in local currency, divided by the cost of a standard basket of local inputs.

2.4 Choosing a Base Location

The quantities for each of the 10 items covering L, M or P inputs for the base location was taken as given and fixed across fifteen cities surveyed for the *roadBLOC* and the nine cities for the *waterBLOC*. This is where the choice of the "base" location becomes crucial: in order to control for the cost of inputs correctly, the standard basket of inputs should be constructed to accurately represent the basket of inputs used across different locations, and thus, the input mix in the base location should be as similar as possible to that used in other locations.

[4] For the avoidance of doubt, "PPP" in this paper refers to purchasing power parity effects in the construction of infrastructure, as opposed to the PPP of consumer prices.

[5] The methodology adjusts for these input prices because they reflect factors beyond the control of the infrastructure sector, e.g. labor market conditions, supply and demand for capital inputs, etc. If overall project costs are used without adjusting for input costs, one would not know whether these are due to the efficiency/performance of the infrastructure sector itself, or other cost sources outside the sector. This study, therefore, adjusts for input costs so that the cost measure is driven by factors that the infrastructure sector can control as this will be more useful in generating recommendations and insights for infrastructure sector players.

[6] Exchange rates are also determined by factors outside of the control of the infrastructure sector, and it is therefore better that they do not influence the cost measure. See footnote 4 above for further explanation.

[7] i.e., adjusting for both local input prices and differences in the strength of national currencies.

Istanbul was selected as the base location for this paper because its share of inputs was likely to be a good representation of other emerging and developing Asian cities for the following reasons:

- Turkey is an emerging economy in Asia with relatively good infrastructure and construction capacity. Based on the World Economic Forum (2019) Global Competitiveness Index, the country ranks 49th out of 141 surveyed countries in the Infrastructure Pillar,[8] above Kazakhstan (67th), Indonesia (72nd) and Philippines (96th), although below Australia (29th).

- Turkey's large construction sector is not only active in its domestic economy but has also participated in projects in many Asian countries. Turkey ranks second in terms of Engineering News-Record's (ENR) 2019 Top 250 International Contractors[9] with 44 Turkish companies included in the list, ranking only behind China (ENR, 2019). Further, since the early 1970s, Turkish contractors have operated across 126 different countries involving close to 10,000 projects worth about USD400 billion on aggregate (Turkish Contractors Association, 2019). Hence, there is a greater likelihood that Turkey's input mix is representative of that in other locations.

- Turkey's labor income share as a proportion of GDP is 36 percent based on (International Labor Organization, 2019) estimates for the year 2017 (latest available data). This statistic is close to that of other countries surveyed, such as Indonesia (38 percent) and Egypt (35 percent). Turkey's share also falls between that of the Philippines (27 percent) and Russia (52 percent). Again, this means that the mix of capital and labor in Turkey's construction sector is likely to be not too dissimilar to those of other Asian countries.

The benchmark for comparison has been defined, and the choice of the base location selected. Therefore, the next section discusses data.

3 Data

The previous section discussed the importance of an infrastructure construction cost benchmark that is invariant to local input costs and currency fluctuation. This section discusses the composition of the benchmark and quantities. The locations selected for the study and quantities are explained below. Similarly, the next section then discusses why a four-lane arterial urban road and a 125 Million Liters per Day (MLD) water treatment plant were chosen as standard archetypes for comparison.

3.1 Locations under study

The study uses data from 15 cities, out of which 14 are from developing and emerging economies whereas one is from a developed country (

[8] This pillar measures performance related to transport infrastructure (road, railroad, airport, etc.) and utility infrastructure (electricity and water supply).
[9] The list ranks firms according to contracting revenue from projects outside their respective home countries.

Table 1). Sydney (Australia) was added to provide context for a developed country with a high labor-cost profile for comparison purposes.[10] While all locations were surveyed for *roadBLOC*, not all were surveyed for *waterBLOC* due to time and resource limitations. Hence, *roadBLOC* compares costs across 15 cities, and *waterBLOC* compares costs across 9 cities.

Table 1: Locations for *roadBLOC* and *waterBLOC*

City	Country	Currency	Surveyed for *roadBLOC*	Surveyed for *waterBLOC*
Almaty	Republic of Kazakhstan	KZT		
Bangalore*	Republic of India	INR		
Cairo	Arab Republic of Egypt	EGP		
Colombo	Democratic Socialist Republic of Sri Lanka	LKR		
Delhi	Republic of India	INR		
Dhaka	People's Republic of Bangladesh	BDT		
Ho Chi Minh City*	Socialist Republic of Viet Nam	VND		
Islamabad	Islamic Republic of Pakistan	PKR		
Istanbul*	Republic of Turkey	TRY		
Jakarta*	Republic of Indonesia	IDR		
Manila	Republic of the Philippines	PHP		
Moscow*	Russian Federation	RUB		
Shanghai*	People's Republic of China	CNY		
Sydney*	Commonwealth of Australia	AUD		
Tashkent	Republic of Uzbekistan	UZS		

Note: Cities marked (*) are included in Turner and Townsend (2019).

3.2 Data Collection Process

Data collection in this study was a two-stage process. The first stage involved finding the unit cost of inputs in the basket in each city in local currency. Items in the basket were then weighted according to the product mix of the base location, Istanbul. To obtain this data, the Economist Intelligence Unit (EIU) surveyed construction companies in each of the 15 cities. In every city under the study, the EIU also conducted one or two construction industry expert interviews, which lasted for about 30 minutes each. The sample sheet of such interviews can be found in the annex. Through these interviews and surveys, per unit costs (see an example for Shanghai in Table 2) were collected. These per unit costs were multiplied by the respective fixed quantities of the basket constituents from Istanbul. The average of these costs is the cost of a "standard basket" of inputs in local currency or Statistic A. An important requirement is that the fifth column must have approximately equal values (i.e. all basket items have equal weight) in order to control of quantity, so the second column was formulated to meet this outcome.

[10] Australia has an estimated 57 percent labor income share (International Labor Organization, 2019).

Table 2: Method to compute the cost of a standard basket of inputs (Statistic A)—Istanbul (base) and Shanghai (example)

Items (ID)	Quantity (Istanbul)	Cost/Unit (Istanbul)	Total Cost (Istanbul)	Quantity (same as Istanbul)	Cost/Unit (Shanghai)	Total Cost (Shanghai)
L_1	QL_1	CL_{1I}	QL_1 X CL_{1I}	QL_1	CL_{1s}	QL_1 X CL_{1S}
L_2	QL_2	CL_{2I}	QL_2 X CL_{2I}	QL_2	CL_{2S}	QL_2 X CL_{2S}
L_3	QL_3	CL_{3I}	QL_3 X CL_{1I}	QL_3	CL_{3S}	QL_3 X CL_{1S}
M_1	QM_1	CM_{1I}	QM_1 X CM_{1I}	QM_1	CM_{1s}	QM_1 X CM_{1S}
M_2	QM_2	CM_{2I}	QM_2 X CM_{2I}	QM_2	CM_{2s}	QM_2 X CM_{2S}
M_3	QM_3	CM_{3I}	QM_3 X CM_{3I}	QM_3	CM_{3S}	QM_3 X CM_{3S}
M_4	QM_4	CM_{4I}	QM_4 X CM_{4S}	QM_4	CM_{4S}	QM_4 X CM_{4S}
P_1	QP_1	CP_{1I}	QP_1 X CP_{1I}	QP_1	CP_{1s}	QP_1 X CP_{1S}
P_2	QP_2	CP_{2I}	QP_2 X CP_{2I}	QP_2	CP_{2s}	QP_2 X CP_{2S}
P_3	QP_3	CP_{3I}	QP_3 X CP_{3I}	QP_3	CP_{3S}	QP_3 X CP_{3S}
	Basket	=	$\frac{\Sigma \text{ Total Cost}}{10\text{(no. of items)}}$	Basket	=	$\frac{\Sigma \text{ Total Cost}}{10\text{(no. of items)}}$
	PPP Exchange Rate	=	$\frac{\text{Basket(Istanbul)}}{\text{Basket(Istanbul)}}$	PPP Exchange Rate	=	$\frac{\text{Basket(Shanghai)}}{\text{Basket(Istanbul)}}$

Note: Q = quantity, C = cost, L = labor, M = material, P = plant and machinery

The second stage of the data collection process was to find the cost of construction (per meter of road, or megaliter per day (MLD) of water treatment plant capacity) in each city in local currency (referred to hereafter as cost/m or cost/MLD). Data on cost/m or cost/MLD or statistic B were collected either through sample contract prices or industry professional costing. Costs were estimated in 2019 terms and were verified against known prices of projects that have already been contracted, where available, and from secondary sources such as case study projects or online.

The *roadBLOC* and *waterBLOC* indices were computed by dividing cost/m or cost/MLD (Statistic B) by the costs of standard baskets of inputs (Statistic A) (for road and water infrastructure, respectively).

Some issues related to data samples were uncovered during the data collection process. In particular, some data were missing, as the practitioners were in some cases unable to provide prices for some items. Also, due to the small number of interviews per city, estimates for each item may vary from the respective true cost for that item. Based on these concerns, this paper uses expert judgment by considering the mean, median or mode of interview answers for every city under study. For *roadBLOC*, data used in this paper are those collected through interviews and cost figures for a similar exercise conducted during the past year, and appropriate inflation rates sourced from www.tradingeconomics.com have been applied to update these costs.

For *waterBLOC*, a significant proportion of the data (13 percent) were missing and had to be estimated using secondary sources. A much smaller proportion of the sample (1.5 percent) was judged to be potentially erroneous and thus corrected using the abovementioned approaches where necessary.

4 A Discussion on Infrastructure Archetypes for Road and Water

This paper thus far has presented the methodology on how data was collected, and how each BLOC was computed. It is important at this stage to discuss how the infrastructure archetype(s) for road and water were selected. This selection procedure presents the reader with a deeper insight on the methodology, and an understanding of the strengths and limitations of this benchmarking exercise. This discussion on archetypes also serves as a robustness check on the main results.

4.1 Road Infrastructure

4.1.1 Archetypes

Five archetypes of road projects that are common across different cities and geographies are considered. These archetypes are described in Table 3.

Table 3: Road Archetypes

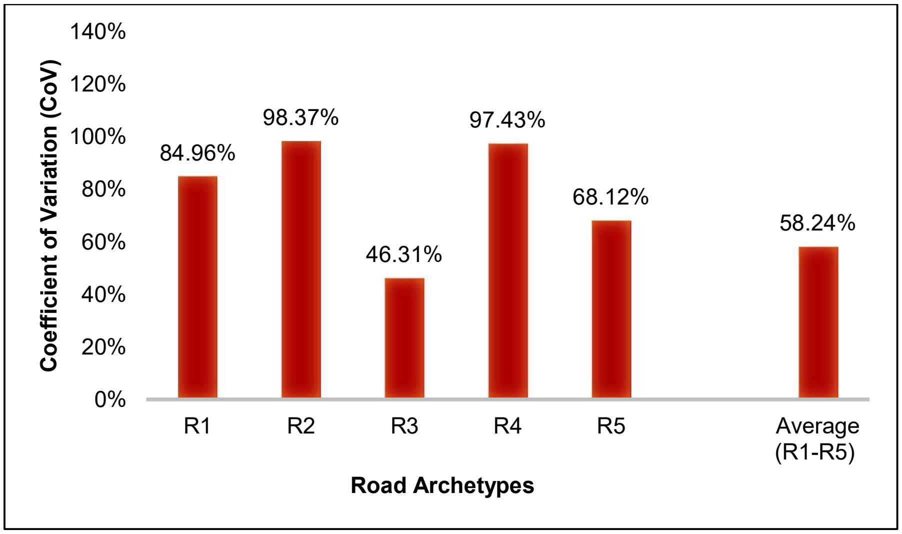
ID	**Description** (based on Asian Highway standards)	Unit*
R1	Two-lane country road [Class II]	m
R2	Four-lane existing urban arterial road resurfacing [Class I]	m
R3	Four-lane urban arterial road including traffic-controlled intersections [Class I]	m
R4	As last, but on elevated post-tensioned concrete bridge (10m high pylons)	m
R5	Six-lane divided motorway including bridgework, overpasses and off-ramps [Primary]	m

Note: meters are used in preference to kilometers to avoid handling large numbers.

Project-level data on each of the archetype were collected. The main objective of this exercise was to determine which archetype has the lowest variation among the locations chosen. The lower the variation (measured through the Coefficient of Variation (CoV)), the better it is for the archetype to be a standard for comparison across locations. CoV is used as a test for the Law of One Price[11], and the method with the lowest CoV best reflects purchasing power parity (Langston, 2019) (Langston, 2014) (Langston, 2016). In an ideal world, where this law holds, the CoV will be zero, but due to transaction costs and trade frictions, in practice it would never fully hold. However, the closer the CoV gets to zero indicates the result that best reflects PPP. Based on this, R3 was chosen as it has the least Coefficient of Variation (CoV) among the other archetypes. These results are shown in Figure 1.

[11] According to the "law of one price" (Woodrow, 1901), prices of the same commodity should be similar across countries. To the extent that this holds, one would expect the costs of construction to be similar across countries.

Figure 1: Comparing the Coefficient of Variation between Road Archetypes



4.1.2 *roadBLOC* Basket

The next step was to create the inputs for the BLOC basket. Based on Australia's Bureau of Infrastructure, Transport, and Regional Economies (BITRE, 2016), a resource mix of L=30 percent, M=40 percent and P=30 percent was assumed. This proportion of resource mix dictates the composition of the ten basket inputs for this archetype.

Table 4 lists the *roadBLOC* basket items collected.

Table 4: *roadBLOC* Basket Items

ID	Description	Unit	
L1	Site engineer	hour	*L = 30% (3 items)*
L2	Land surveyor	hour	
L3	Traffic controller	hour	
M1	1-20mm crushed aggregate roadbase	t	*M = 40% (4 items)*
M2	600mm diam. reinforced concrete drainage pipe	m	
M3	Hot mix asphaltic concrete	t	
M4	SL82/F82 fabric reinforcement	m^2	
P1	Hire 300 kW open bowl scraper + operator + fuel	day	*P = 30% (3 items)*
P2	Hire 150 kW track asphaltic paver + operator + fuel	day	
P3	Hire off-highway 50t articulated truck + operator + fuel	day	

As discussed in the section above, the paper considers the quantities needed for constructing R3 in Istanbul, the base city. By fixing these quantities across all other cities, the paper controls for quantities and quality (considering one road archetype only). By controlling for quantities and quality (considering one road archetype only), any cost differential is expected to arise from non-quantity and non-quality measures. Table 5 presents the quantities for each of the *roadBLOC* basket items.

Table 5: Quantities for *roadBLOC* inputs (with Istanbul as the base location)

ID	Description	Unit	Quantity
L1	Site engineer	hour	555
L2	Land surveyor	hour	925
L3	Traffic controller	hour	975
M1	1-20mm crushed aggregate roadbase	t	925
M2	600mm diam. reinforced concrete drainage pipe	m	194
M3	Hot mix asphaltic concrete	t	23
M4	SL82/F82 fabric reinforcement	m^2	689
P1	Hire 300 kW open bowl scraper + operator + fuel	day	6
P2	Hire 150 kW track asphaltic paver + operator + fuel	day	7
P3	Hire off-highway 50t articulated truck + operator + fuel	day	11

4.2 Water Infrastructure

4.2.1 Archetypes

As in the case of *roadBLOC*, this paper considered five archetypes of water treatment projects that are common across different cities and geographies. These archetypes are described in Table 6.

Table 6: Water Archetypes

ID	Description	Unit*
W1	125 MLD sewage treatment plant to service a medium-sized urban settlement, discharging into local estuaries	MLD
W2	As W1, but comprising on site storage tanks and a higher level of treatment, e.g. using Moving Bed Biofilm Reactor (MBBR) technology, suitable for industrial purposes	MLD
W3	125 MLD water filtration/sanitation plant sourcing natural water resources	MLD
W4	As last, but including above-ground main supply pipework between water resource and plant (assume 5km distance)	MLD
W5	125 MLD desalination plant as an alternative supply of fresh drinking water	MLD

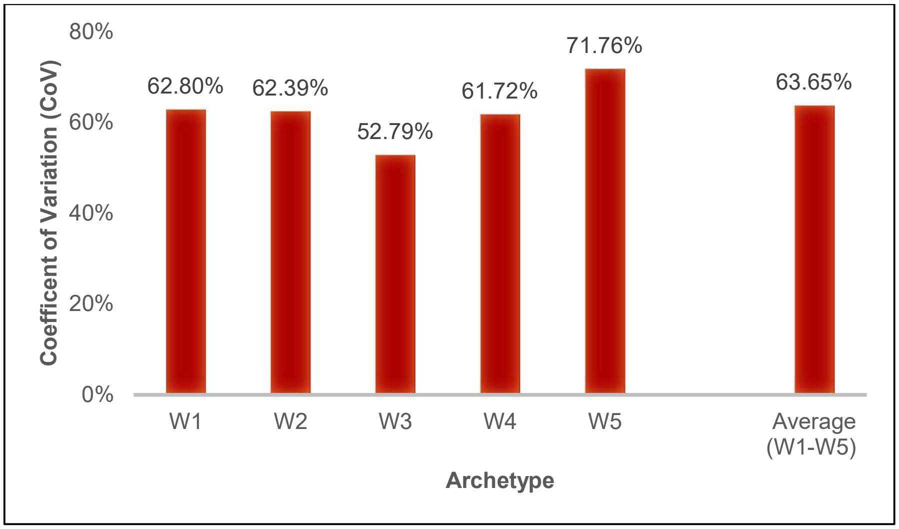
Note: MLD (megalitres/day) is used in preference to litres/day to avoid handling large numbers.

Data for each of these projects were collected, including ground works, tanks, reticulation pipework on site, computer controls, valves, building works, perimeter fencing and other incidental work. The main objective of this exercise, as in the case of *roadBLOC*, was to determine which archetype has the lowest variation among the city-locations.

Contract prices for the five water treatment infrastructure types have high variances, with a CoV at 64 percent on average. Among water treatment projects, W3 has the least CoV, closest to the Law of One Price. This suggests that W3 is a reliable archetype for comparison across locations (Figure 2).

Another reason for this choice was that there are a number of data gaps for prices in W1, W2, W4 and/or W5. Due to missing data, it became necessary to fill these gaps by interpolation from prices in other countries. This approach proved to be unreliable, given substantially high CoV for these archetypes and hence increased W3's strength as an archetype.

Figure 2: Comparing the Coefficient of Variation between Water Archetypes



4.2.2 *waterBLOC* Basket

The *waterBLOC* basket comprises ten items of labor, material or plant and machinery that reflect common inputs needed to construct a W3 water treatment infrastructure project. Each item has a quantity priced in local currency. For example, in the case of Istanbul (base location), the price of quantities was expressed in Turkish Lira (TRY). As in the case of *roadBLOC*, these quantities were fixed and applied to each of the other study locations.

The resource mix for water treatment infrastructure varies depending on the service type, but material supply is likely to have the highest proportion for projects with a significant component of water purification and related technology.[12] No information was found about the appropriate mix of labor, material and plant for these types of projects. However, data were found for energy generation projects (Deloitte, 2014; 2016), which are considered to have a similar taxonomy. Therefore, the estimated mix for *waterBLOC* was interpreted as approximately 30 percent labor (L), 60 percent material (M) and 10 percent plant (P) for the base location. These weights were subsequently applied to other study locations. Table 7 lists the *waterBLOC* basket items collected:

[12] Note that the archetype, W3, is a water filtration plant.

Table 7: *waterBLOC* Basket Items

ID	Description	Unit	
L1	Senior hydraulic engineer	hour	*L = 30% (3 items)*
L2	Junior civil engineer	hour	
L3	Plumber	hour	
M1	50 MPa high strength concrete	m^3	*M = 60% (6 items)*
M2	300mm C-section zinc-coated steel roof purlin	m	
M3	Composite panel insulated roof/wall cladding	m^2	
M4	25mm thick galvanized steel grid flooring	m^2	
M5	600mm wide galvanized steel cable tray	m	
M6	250mm diam. stainless steel flanged pressure pipe	m	
P1	Hire 24t tower crane + 3-person crew + fuel (excl. setup)	day	*P = 10% (1 item)*

Water treatment infrastructure projects require a certain quantity (expressed in specific units) for every input. To control for variations in input quantities across locations, input quantities for Istanbul (the base location) throughout the *waterBLOC* study locations were used, as in the case of *roadBLOC*. Table 8 presents the quantities for each of the *waterBLOC* basket items.

Table 8: Quantities for *waterBLOC* inputs (with Istanbul as the base location)

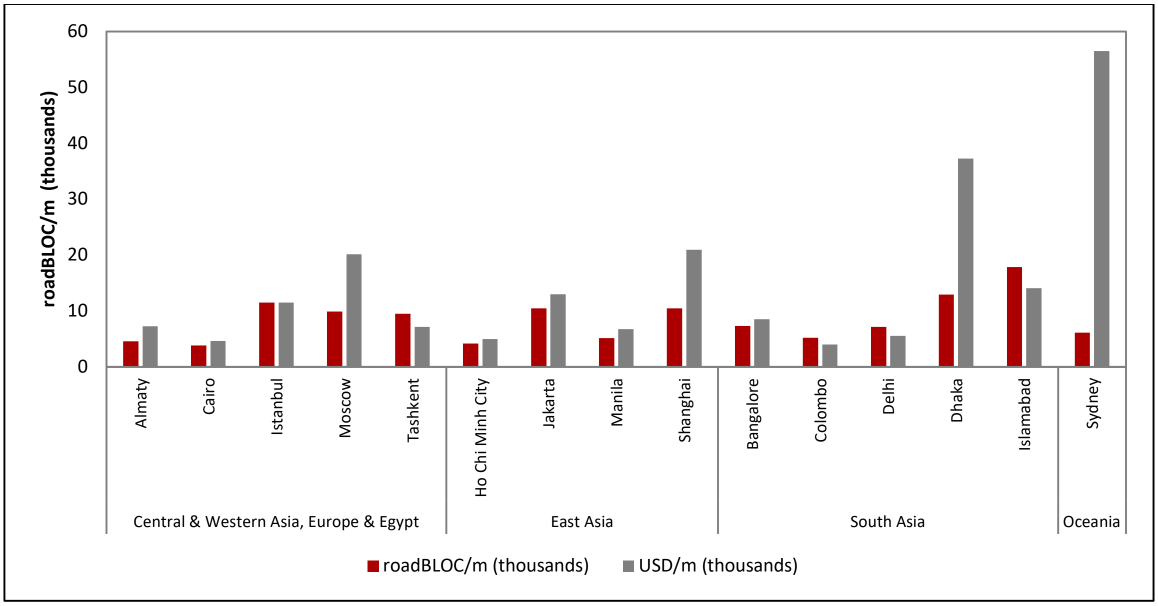
ID	Description	Unit	Quantity
L1	Senior hydraulic engineer	hour	517
L2	Junior civil engineer	hour	672
L3	Plumber	hour	1,033
M1	50 MPa high strength concrete	m^3	52
M2	300mm C-section zinc-coated steel roof purlin	m	158
M3	Composite panel insulated roof/wall cladding	m^2	170
M4	25mm thick galvanised steel grid flooring	m^2	64
M5	600mm wide galvanised steel cable tray	m	197
M6	250mm diam. stainless steel flanged pressure pipe	m	20
P1	Hire 24t tower crane + 3-person crew + fuel (excl. setup)	day	7

5 Results

5.1 Road Infrastructure Costs

The *roadBLOC* approach suggests that Islamabad has the highest cost of building a four-lane arterial road, after controlling for quality, quantity and local input prices. Results also suggest that Cairo is cheapest. Figure 3 results can be interpreted as the following: In Islamabad, 17,873 *roadBLOC* baskets are required to construct one meter of a four-lane arterial road, whereas in Cairo, only 3,888 *roadBLOC* baskets are required to construct one meter of the same road.

Figure 3: *roadBLOC*/m vs. USD/m

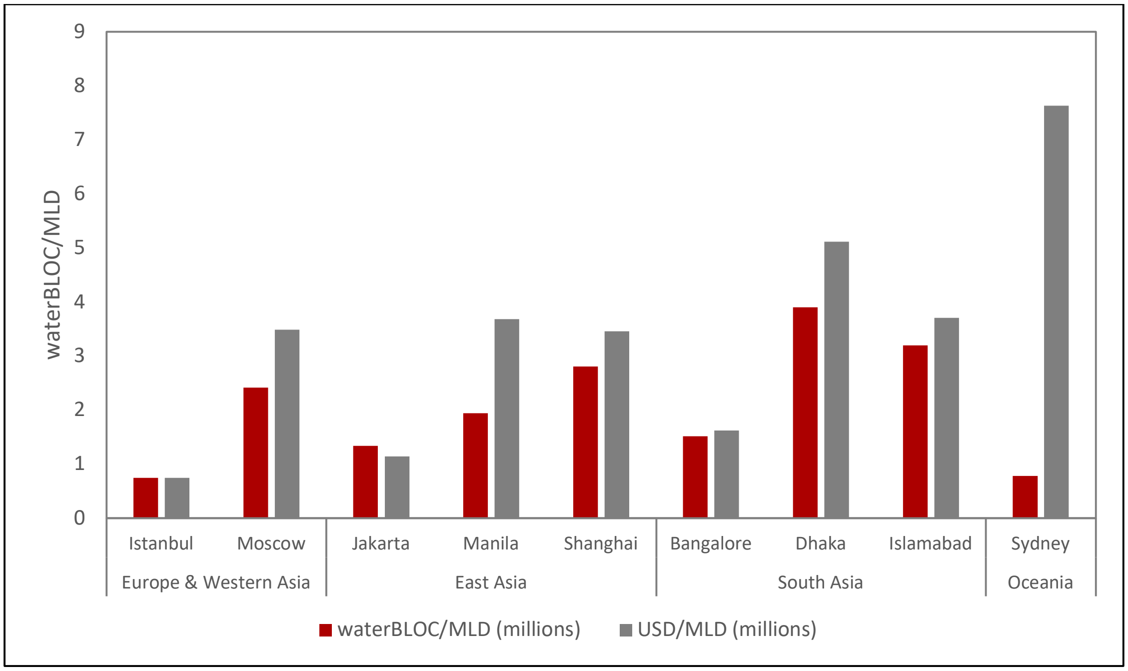


On average, it takes 8,438 *roadBLOC* baskets to construct one meter of a four-lane road. Relative to this average, it is more expensive to build roads in Shanghai, Moscow, Jakarta, Dhaka, Islamabad, Istanbul and Tashkent. In contrast, it is cheaper to build roads in Manila, Delhi, Ho Chi Minh City, Cairo, Bangalore, Colombo, and Almaty.

5.2 Water Infrastructure Costs

The *waterBLOC* approach suggests that, among locations studied, Dhaka has the highest cost for building a 125 MLD water filtration/sanitation plant. In comparison, it is least costly in Istanbul. Figure 4 results can be interpreted as the following: In Dhaka, close to 4 million waterBLOC baskets are required to construct one MLD of a water treatment infrastructure, whereas in Istanbul, close to 750,000 baskets are needed to construct similar infrastructure.

Figure 4: *waterBLOC/*MLD vs. USD/MLD



On average, it takes 2,070,358 *waterBLOC* baskets to construct one MLD of a water treatment infrastructure. Relative to this average, it is more expensive to build a water filtration/sanitation plant in Dhaka, Islamabad, Shanghai and Moscow. In contrast, it is cheaper to build a similar infrastructure in Manila, Bangalore, Jakarta, Sydney and Istanbul.

5.3 Implications of *roadBLOC* and *waterBLOC* results

In general, higher values indicate that it is more expensive to build in a location relative to another. Cost differentials among city-locations can be due to other factors unaccounted for in terms of quality, quantity and local input prices, including productivity ranges based on the availability of resources (including transportation distances) and contractor margins that take heed of market conditions. Moreover, standards of construction, statutory requirements, local practices and concern for worker health and safety can also impact on costs and performance.

High costs for certain city-locations may also be due to challenges specific to their respective contexts. In Dhaka's case for example, high contract prices in road and water infrastructure may be due to local factors such as potential governance challenges or shortages of key resources (The Daily Star, 2017) (Ahmed, n.d.).

6 Conclusion

Infrastructure construction costs are difficult to collect due to the difference in the nature of infrastructure, heterogeneity within the infrastructure groups, and heterogeneity among country conditions. This study acknowledges these constraints and attempts to create a comparable price that can reflect underlying cost structures that is not affected by currency fluctuations. By creating a basket of commodities (based on one particular city), the BLOC method (*roadBLOC* and *waterBLOC)* calculates the number of baskets required to build a meter of a four-lane arterial highway in the case of road infrastructure, and a 125 MLD water filtration/sanitation plant sourcing natural water resources in the case of water infrastructure. The selection of a particular basket controls for both quality and quantity and using baskets as a measure of cost controls for the effects of exchange rate fluctuations and differences in local input prices. Hence the variation in *roadBLOC* and *waterBLOC* costs can be attributed to factors other than quality, quantity, local input prices and the exchange rate. This means that differences in the two indices are likely to be due to factors that are more specific to the infrastructure sector, and that are, as such, within the control of infrastructure stakeholders.

The analysis shows that even after accounting for quantity, quality and local input prices, road and water treatment costs are heterogenous. By using Istanbul, a city that is situated in an emerging economy and has infrastructure that reflects a median position in terms of quality, as the base location, this paper has shown that Dhaka and Islamabad have higher costs of construction for both road and water infrastructures.

Although there are limitations to this study, such as limited number of samples and accuracy of data, the results of this paper could be the first step toward building an evidence base that policy makers and infrastructure professionals could use to examine and address cost-related issues in road and water infrastructure.

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Annex 1: Sensitivity Tests—Change in Base Location

A. *roadBLOC*

This section illustrates how changing the base location from one city to another results in changes in Basket of Locally-Obtained Commodities (BLOC) and hence the final result. For this discussion, Sydney is considered as an alternative base location. As Sydney'sresource mix is different from that of Istanbul, the BLOCs are expected to change.

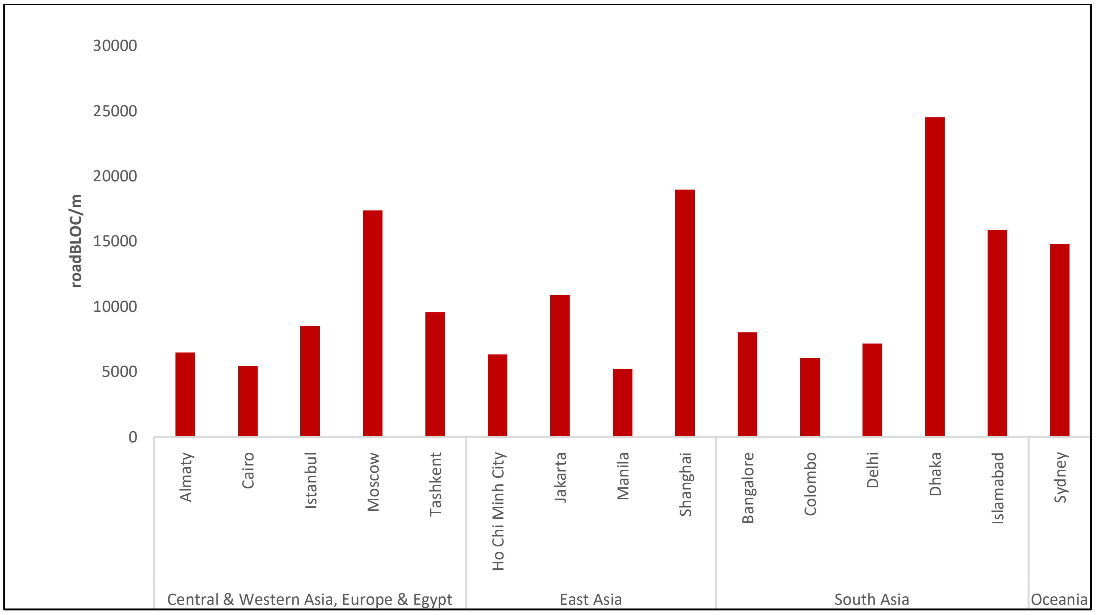
In the case of *roadBLOC*, Table 9 presents the following quantities used considering Sydney as the base location. Comparing Table 5 and Table 9, it can be observed that Sydney is both less labor-intensive and more plant-efficient than Istanbul.

Table 9: Quantities for *roadBLOC* inputs (Sydney as the base location)

ID	Description	Unit	Quantity
L1	Site engineer	hour	110
L2	Land surveyor	hour	92
L3	Traffic controller	hour	200
M1	1-20mm crushed aggregate roadbase	t	155
M2	600mm diam. reinforced concrete drainage pipe	m	80
M3	Hot mix asphaltic concrete	t	80
M4	SL82/F82 fabric reinforcement	m^2	1731
P1	Hire 300 kW open bowl scraper + operator + fuel	day	7
P2	Hire 150 kW track asphaltic paver + operator + fuel	day	7
P3	Hire off-highway 50t articulated truck + operator + fuel	day	7

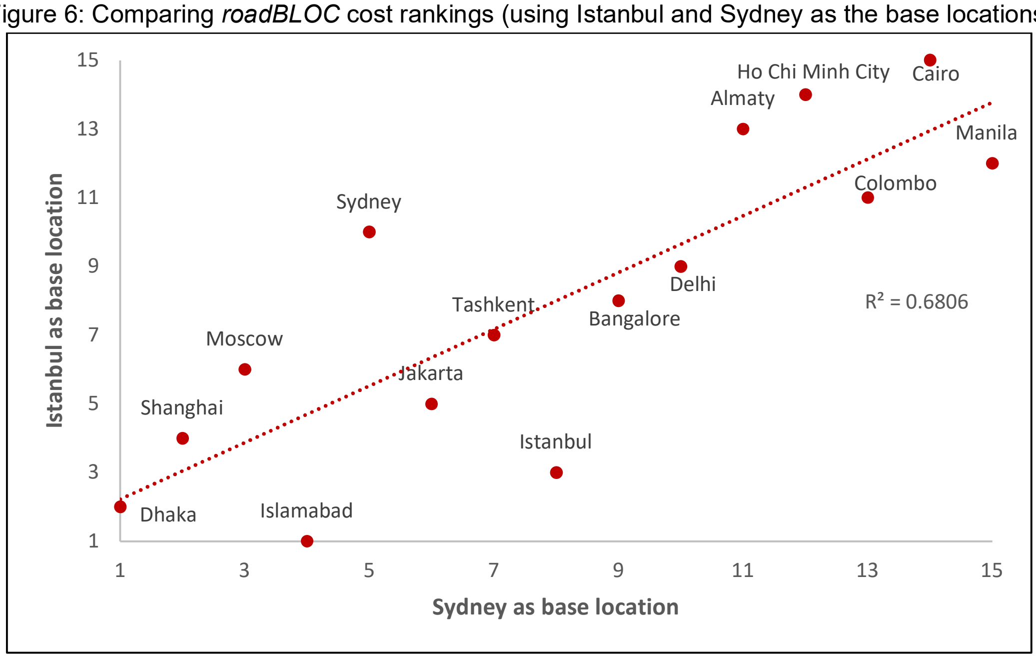
Figure *5* suggests that Dhaka is the most expensive city as it requires 24,510 baskets to construct one meter of an R3 road whereas Manila is the cheapest.

Figure 5: *roadBLOC*/m (Sydney as the base location)



Comparing cost-ranking results among study locations considering changes in the base location, it can be observed that results are generally consistent whether Istanbul or Sydney is used as the base—the R-squared between rankings for the two different base locations is 68 percent. Given that Istanbul and Sydney are quite different cities in terms of levels of economic development, this suggests that the findings are robust to different choices in the base location. That said, there may be discrepancies in cost rankings due to changes in the input mix.

Figure 6: Comparing *roadBLOC* cost rankings (using Istanbul and Sydney as the base locations)



Note: Cities are ranked in terms of cost (with 1 as the most expensive and 9 as the least expensive)

B. *waterBLOC*

Considering a change in base location to Sydney, Table 10 presents the following quantities used to recalculate *waterBLOC*.

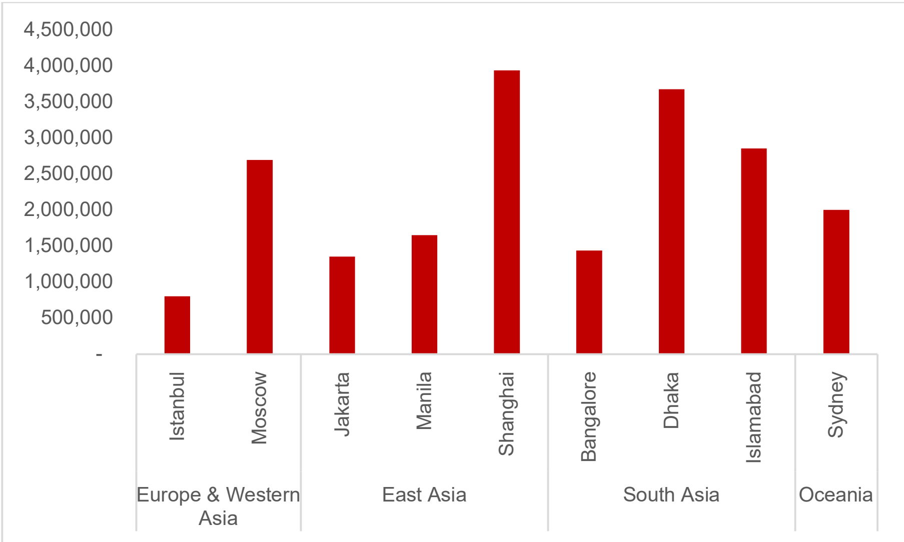
Table 10: Quantities for *waterBLOC* inputs (Sydney as the base location)

ID	Description	Unit	Quantity
L1	Senior hydraulic engineer	hour	96
L2	Junior civil engineer	hour	131
L3	Plumber	hour	144
M1	50 MPa high strength concrete	m^3	58
M2	300mm C-section zinc-coated steel roof purlin	m	262
M3	Composite panel insulated roof/wall cladding	m^2	288
M4	25mm thick galvanised steel grid flooring	m^2	53
M5	600mm wide galvanised steel cable tray	m	480
M6	250mm diam. stainless steel flanged pressure pipe	m	24
P1	Hire 24t tower crane + 3-person crew + fuel (excl. setup)	day	4

Contract prices expressed in number of *waterBLOC* standard baskets are provided in

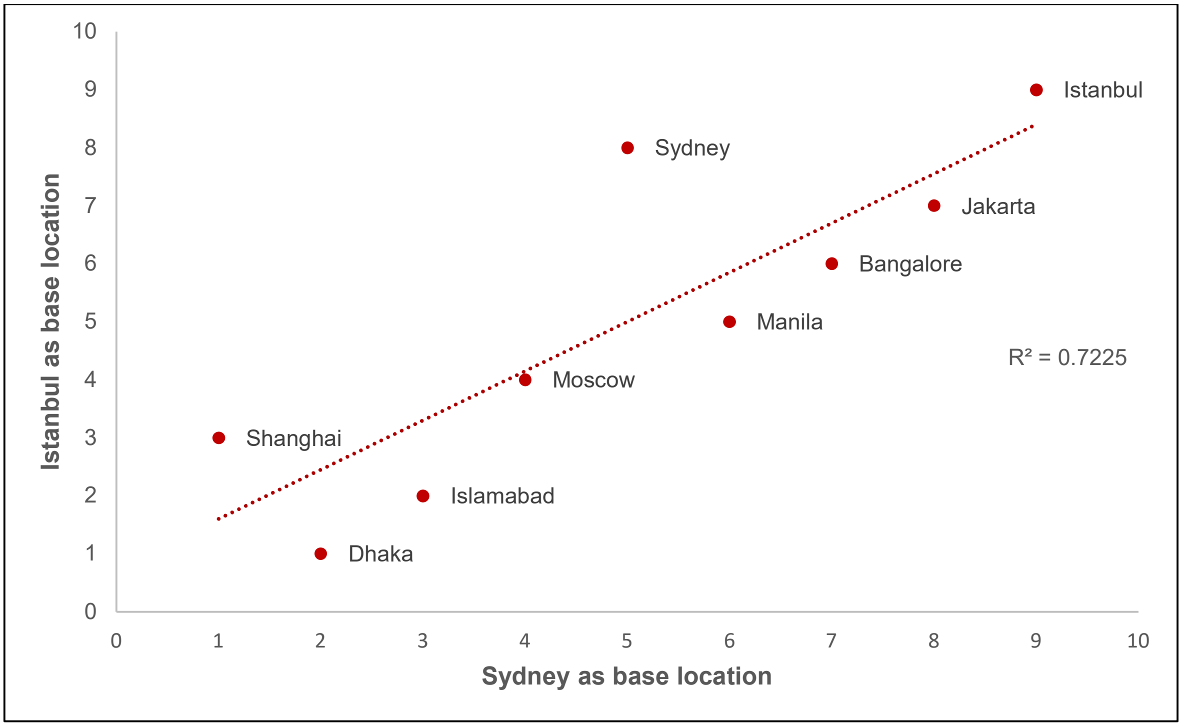
Figure 7. With Sydney as base location, the mean W3 cost is 2,267,132 *waterBLOC*/MLD, considerably higher than the mean using Istanbul as base location. Further, it takes Shanghai 3.9 million *waterBLOC* baskets to construct one MLD of a 125 MLD water filtration/sanitation plant. Shanghai, under this scenario, has the highest cost, followed by Dhaka. Nonetheless, Istanbul remains the least expensive location, similar to the case where Istanbul is the base case scenario.

Figure 7: *waterBLOC*/MLD (Sydney as the base location)



Comparing the ranking of cities (with 1 as the most expensive and 9 as the least expensive) using Istanbul and Sydney as base cases shows a relatively strong positive relationship, with R-squared at 72 percent (Figure 8). Again, this suggests that the results regarding which city has the highest cost using *waterBLOC* are robust to the choice of base location.

Figure 8: Comparing *waterBLOC* cost rankings (using Istanbul and Sydney as the base locations)



Annex 2: Sample List of Questions – Istanbul example

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DATA SHEET: road construction

City:	Istanbul (Base)
Currency:	TRY
Tendering:	cold/warm/hot

Please complete shaded column - assume large work quantities

ID	Supply Only Prices (excluding delivery and overheads)	Unit	Local Cost/Unit	
			2018	2019
L1	Site engineer #	hour	30	35
L2	Land surveyor #	hour	18	21
L3	Traffic controller #	hour	17	20
M1	1-20mm crushed aggregate roadbase #	t	18	21
M2	600mm diam. reinforced concrete drainage pipe #	m	86	99
M3	Hot mix asphaltic concrete #	t	750	863
M4	SL82/F82 fabric reinforcement #	m^2	24	28
P1	Hire 300 kW open bowl scraper + operator + fuel #	day	2,940	3,420
P2	Hire 150 kW track asphaltic paver + operator + fuel #	day	2,137	2,457
P3	Hire off-highway 50t articulated truck + operator + fuel #	day	1,386	1,594

 # important items (must be completed)

ID	Comparative Prices (including cut and fill earthworks)	Unit	Local Cost/Unit	
			2018	2019
R1	Two-lane country road [Class II]	m	2,500	2,875
R2	Four-lane existing urban arterial road resurfacing [Class I]	m	5,000	5,750
R3	Four-lane urban arterial road including traffic-controlled intersections [Class I] #	m	10,000	11,500
R4	As last, but on elevated post-tensioned concrete bridge (10m high pylons)	m	39,500	45,425
R5	Six-lane divided motorway including bridgework, overpasses and off-ramps [Primary]	m	19,500	22,425

 # important items (must be completed)

DATA SHEET: water treatment

City:	Istanbul (Base)
Currency:	TRY
Tendering:	cold/**warm**/hot

Please complete shaded column - assume large work quantities

ID	Supply Only Prices (excluding delivery and overheads)	Unit	Local Cost/Unit	
			2018	2019
L1	Senior hydraulic engineer #	hour	n/a	26
L2	Junior civil engineer #	hour	n/a	20
L3	Plumber #	hour	n/a	13
M1	50 MPa high strength concrete #	m^3	n/a	255
M2	300mm C-section zinc-coated steel roof purlin #	m	n/a	85
M3	Composite panel insulated roof/wall cladding #	m^2	n/a	79
M4	25mm thick galvanized steel grid flooring #	m^2	n/a	210
M5	600mm wide galvanized steel cable tray #	m	n/a	68
M6	250mm diam. stainless steel flanged pressure pipe #	m	n/a	675
P1	Hire 24t tower crane + 3-person crew + fuel (excl. setup) #	day	n/a	2,000

 # important items (must be completed)

ID	Comparative Prices (all inclusive)	Unit	Local Cost/Unit	
			2018	2019
W1	125 MLD sewage treatment plant to service a medium-sized urban settlement, discharging into local estuaries	MLD	n/a	594,259
W2	As last, but comprising on site storage tanks and a higher level of treatment, e.g. using Moving Bed Biofilm Reactor (MBBR) technology, suitable for industrial purposes	MLD	n/a	1,086,578
W3	125 MLD water filtration/sanitation plant sourcing natural water resources #	MLD	n/a	747,500
W4	As last, but including above-ground main supply pipework between water resource and plant (assume 5km distance)	MLD	n/a	1,303,894
W5	125 MLD desalination plant as an alternative supply of fresh drinking water	MLD	n/a	3,565,554

 # important items (must be completed)