USING SPREADSHEET MODELS FOR ESTIMATING COLLECTION COSTS FOR RESIDENTIAL AND COMMERCIAL CUSTOMERS

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ABSTRACT
Seattle Public Utilities (SPU) developed two spreadsheet models to estimate collection costs. The models consider variations in collection frequency, truck types, material separation requirements, transfer points, and more. These models were used by SPU as part of an effort to estimate total solid waste system costs, considering collection all the way through disposal or processing, in order to evaluate alternative future visions for Seattle's solid waste system. They were also used to determine the variables having the most impact on cost, and the relative cost impacts of changes in parameters. This paper describes the two collection cost estimation models:

- Single Family Residential Collection Costs
- Multi-family and Commercial Collection Costs

Included are descriptions of the input data used, the model methodologies, the outputs obtained, and a discussion of how the results can be used. Increasingly, municipalities will be called upon to make difficult choices in balancing the level of solid waste services provided and the cost of those services, and models like these will be helpful in characterizing the options.

INTRODUCTION
The path garbage takes from homes and businesses to the landfill involves several steps, and similarly for yard waste and recyclables in getting to their final processing locations. Typically, a material is *collected* from homes and businesses, taken to a *transfer* station where it is consolidated for *short or long haul* to a disposal or processing location. Each of these steps costs the ratepayer, and changes in one part of this solid waste system may affect costs in other parts of the system.

Seattle Public Utilities developed cost estimation models for each part of the system (collection, transfer, the disposal or processing locations) so that the costs could be summed and compared at the overall level as various system alternatives were considered. The intent was to identify the least-cost overall system, which would not necessarily be the least cost collection scenario. The various analytical tools, collectively called the Recycling Potential Assessment/System Analysis Model, were used to evaluate system options (Seattle Public Utilities, 1999). The results of the solid waste system analysis can be found in Seattle's Solid Waste Plan, *On the Path to Sustainability* (Seattle Public Utilities, 1998).

This article describes the collection cost models. The types of collection alternatives modeled by SPU include:
Single-family
- co-collection and pod trucks
- cost impacts of different collection frequencies
- foodwaste collection alternatives
- recycling program variations, including mandatory separation
- alternative transfer locations

Multi-family and commercial
- alternative transfer locations
- recycling program variations, including mandatory separation

The collection cost estimation spreadsheets developed are also valuable for determining the factors which are most critical to collection efficiency and cost minimization, and for exploring the cost impacts of varying specific collection parameters.

SINGLE FAMILY RESIDENTIAL COLLECTION COST MODEL

Overview of Model

The single-family collection cost model estimates the cost of collecting materials (recyclables, yard waste, and garbage) from residential customers who use household containers (cans, bins, or bundles). A wide variety of collection strategies can be hypothesized and modeled. The spreadsheet allows the user to estimate the approximate total annual costs for a particular scenario, and to explore the cost impacts of varying individual parameters within that scenario. The basic structure of the spreadsheet was developed by Barbara Stevens of Ecodata, Inc.

A scenario was defined by the recycling programs it included, by the particular collection methods used, and by the facilities to which materials were sent. For example, the current household scenario for the City of Seattle would include the collection of yard waste, recyclables, and garbage, with separation of yardwaste being mandatory and the separation of recyclables being voluntary. A dedicated fleet of collection trucks collects each material stream, and materials are directed to two city-owned transfer stations and two private stations. Another scenario may have mandatory separation of recyclables, and yet another may add the collection of foodwaste, with participation being voluntary. Materials may be co-collected, and a different network of transfer stations may be used.

Each "run" of the model requires a complete set of input assumptions, as described in detail in the section below, that characterize a collection scenario. The model allows the user to specify the number of collection fleets and types of trucks, which materials are commingled, number of compartments on trucks, frequency of collection, and destination of the trucks. The model calculates the number of crews required in each fleet, and the total annual costs of each fleet. A fleet of trucks may collect one or multiple material streams, garbage alone for example, or garbage and recyclables co-collected[1]. The collection cost per ton and per household is calculated both for each fleet of trucks, and for the collection system as a whole. This overview of the model is shown in Figure 1.

Collection Model Input Parameters

Below is a list of the parameters used, with indications as to how the appropriate input values were determined for the specific modeling done for Seattle. All of the inputs can be varied, although in practice many of the parameters are constant from run to run.

Material Tonnage and Composition: This parameter describes the total tons that will be included in the collection/transfer/disposal system for a given scenario, broken down into the different streams for collection: garbage, recycling, yardwaste, foodwaste, and/or special collections, as appropriate. Separate waste generation and recycling forecast models were used to predict the total tons to be recycled and disposed in Seattle in 2010[2]; these values were input to the collection model. The forecast models take into account many contributing variables, such as population and household counts, economic activity, and number and size of businesses. Total generation would vary depending on waste reduction efforts, and how the tonnage was distributed between the garbage and collection streams would vary depending on the recycling collection programs included. For instance, if the scenario being considered includes extensive grasscycling promotion, there will be fewer tons of yard waste and fewer overall tons. If the scenario being considered proposes new material to be collected in the curbside recycling program, the total tons will be the same, but tons will shift from the garbage stream to the recycling stream. Tonnage and composition data is entered into the model at three levels: the total tonnage generated, a breakdown of the total into percent composition in twenty categories, and the percent recycled of each of those twenty materials[3].

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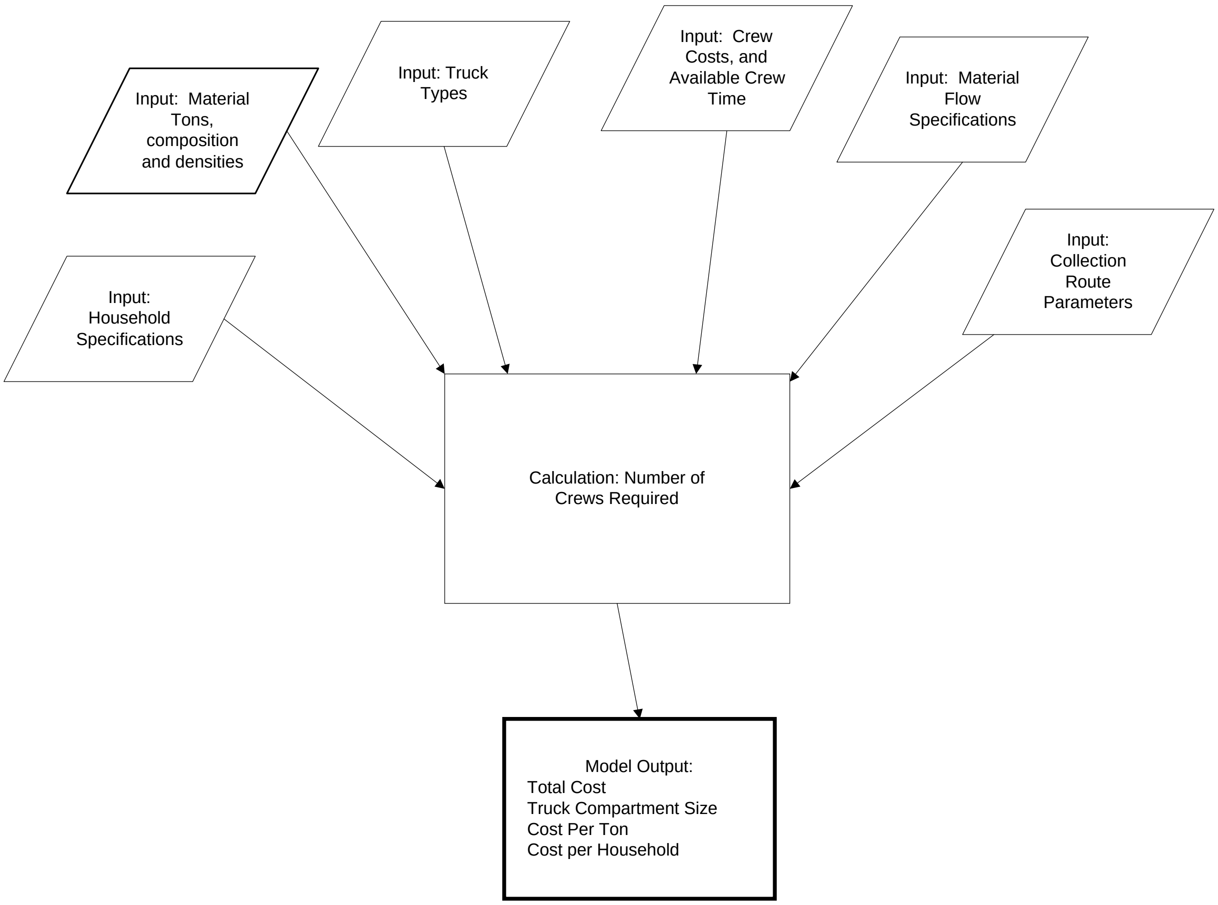
[1] The "material streams" referenced here are different from the twenty "materials" described above. A "material stream" is used here to identify a grouping of materials that are disposed of as a single waste stream, of which this modeling work includes four: "garbage", "recyclables", "yardwaste", and "foodwaste". Yardwaste, for instance, may include the material yardwaste, as well as some vegetative foodwaste and compostable paper.

[2] The year 2010 was selected to allow full implementation of new programs, and to include near-term population and business growth when evaluating facility capacities.

[3] Th e twenty material categories correspond to those used to composition analysis studies of Seattle waste streams.

Figure 1: Single Family Collection Model



<u>Material Densities</u>. The collection model requires density factors for each of the twenty material categories (pounds per cubic yard) for both uncompacted material and compacted material. This allows conversion of tons to cubic yards and is a key determinant in calculating truck capacities. Ecodata furnished the input data on material densities.

<u>Household Level Specifications</u>: The total number of households to be served must be specified, along with participation rates for whichever collection programs are included in the scenario being modeled. Participation is described at two levels: what percent of households choose to receive the service, and of those participating households, what percent of them set out material for collection on each collection opportunity. For modeling Seattle programs, the garbage collection participation rate is 100% (since everyone by law is required to have curbside collection) but the setout rate is less - about 90%. For Seattle's current weekly curbside program collecting from bins, the participation rate is 90% and the setout rate is 70%. For new programs being modeled, participation and setout rates are based on results of pilot programs and/or responses to surveys, or on extrapolation from current program participation rates.

<u>Collection Route Parameters:</u> In order to calculate how many collection crews are required, there are several key collection route parameters that must be specified. These are:

- *Travel Time*, the time to drive from setout to setout (stop to stop), is impacted by household participation and setout assumptions. The lower the setout rate, the greater the distance between each household needing collection and therefor the greater the travel time. The average travel time for Seattle's collection programs ranges from eight to ten seconds.

- *Stop time*, the time spent at each stop placing material in the truck and returning containers, is affected by the truck type (especially semi-automated versus manual) and number of containers. Stop times estimates for the scenarios modeled by SPU varied greatly, from 14 to 55 seconds.
- *Collection frequency*, which is how many times a household receives each collection service per year, varies from weekly to every-other-week to monthly for Seattle residential programs.

For SPU's modeling, route time input numbers were derived from actual data collected en-route for different types of collection trucks. When actual data was not available, judgement was used to develop a set of stop and travel times that are internally consistent with each other.

Truck Types. There are five truck types specified in the base model. These basic truck types are listed in Table 2.

Table 2 Base Truck Types in Single Family Collection Model

COMPONE	One-compartment compaction truck, semi-automatic, with two-way containers. The basic garbage truck.
NOCOMP	Three-compartment non-compaction truck, with small two-way containers. The basic source-separated recycling truck.
NCCOMP	Two-compartment truck, with one compaction chamber and one non-compaction chamber. Semi-automatic, and two-way containers (the containers must be returned to the curb). The basic commingled recycling collection truck; glass is not compacted, the mixed materials are.
COMP TWO	Two-compartment packer, both compaction units. Used for co-collection options.
CONT TRK	A collection truck with a removable compaction container (design is newly introduced and in limited commercial use). Collection trucks take full containers ("pods") to a staging area, and transporter trucks haul up to three containers to the tip destination where the loads are dumped.

A special input allows the truck capacity to be constrained, since it is assumed that in the case of multiple compartments, one compartment will likely fill when another is not yet full, so there will be unused volume at the time the truck must be emptied. The volume capacity for trucks with multiple compartments was reduced by one to two cubic yards to reflect this.

Material Placement and Flow. This input describes which materials are collected in which compartment of which truck, and then to which transfer locations the materials are taken. The model allows several transfer points to be specified by identifying different drop points and indicating what percentage of the fleet goes to each one. A truck also may visit two transfer points, dropping one or more materials at each. For each transfer (or dump) location specified, the average travel time to that location from the route areas being served must be specified. For the SPU modeling work, the travel times between the collection routes and the transfer stations was obtained from a Geographic Information System (GIS) model. The GIS model would identify the optimum driving path from the routes to the transfer location, and calculate the expected drive time according to speed limits and distances. These time estimates were adjusted to consider traffic by determining an appropriate "traffic time adder" from calibration with numerous actual drive times. The estimated time for travel to Seattle transfer stations ranged from 15 to 25 minutes.

Crew Costs. Estimated crew costs include direct labor, supervision, fringe benefits, overhead, vehicle depreciation, and operation and maintenance, which depend on the capital cost of the truck and the size of crew, wage rate, fuel, and insurance requirements. The cost estimates used by SPU were developed by Ecodata, aside from direct labor costs, which were determined by looking at existing labor contracts. A typical annual cost for a one-person crew, including equipment amortization, is in the range of $150 to $160K.

Available Collection Time Per Crew. The user must specify the base hours of a typical work day, and the daily time allocated to each crew for equipment checks, breaks, wash-up, and the time to drive from and back to the base of operations at the beginning and end of each day. SPU allowed 80 minutes of non-collection time per crew per day.

How the Model Works

The model performs a series of calculations using the input parameters described above, some of which the user specifies for each scenario and some of which do not vary across scenarios.

For each fleet of trucks, the model calculates the time required for a crew to collect one full load. This time is the sum of the necessary number of individual household stop times and travel times to give a full load, plus the cycle time to dump that load at a transfer station. The model then determines how many full and partial loads each crew can complete in their daily available collection time, and from that, the total daily tonnage of the crew. From this, the model calculates how many crews are needed to collect all of the tons of that material stream. This calculation is done for each truck type and material combination.

Collection Cost Model Outputs

The model displays two intermediate results which may be of interest to the user:

- ***Number of crews required.*** This is the number of crews needed, on average, to provide the indicated collection services to the designated number of households.
- ***Size of truck compartments:*** The model optimally allocates the total capacity of a truck to its compartments based on the amount and density of the material going to each compartment The information would be useful if the user desired to purchase trucks with multiple compartments.

The main purpose of this model is to estimate collection costs, which are presented in three formats:

- ***Annual collection cost.*** For each fleet of collection trucks, and for all of the fleets together, the model displays the total annual cost. This cost is equal to the number of crews multiplied by the annual crew cost. This is useful to assess gross differences in scenario collection costs.
- ***Cost per ton***. For the tonnage associated with each truck fleet, and for the total collection system tons, the model calculates the annual collection cost per ton. This cost is equal to the annual collection costs divided by the annual tons. This number is useful to identify particularly cost-effective or particularly expensive elements of proposed collection scenarios.
- ***Annual cost per household***. The model presents this number for each fleet of trucks, and for the total collection system. It is equal to the total annual costs divided by the total number of households.

MULTI-FAMILY AND COMMERCIAL COLLECTION COST MODEL

Overview

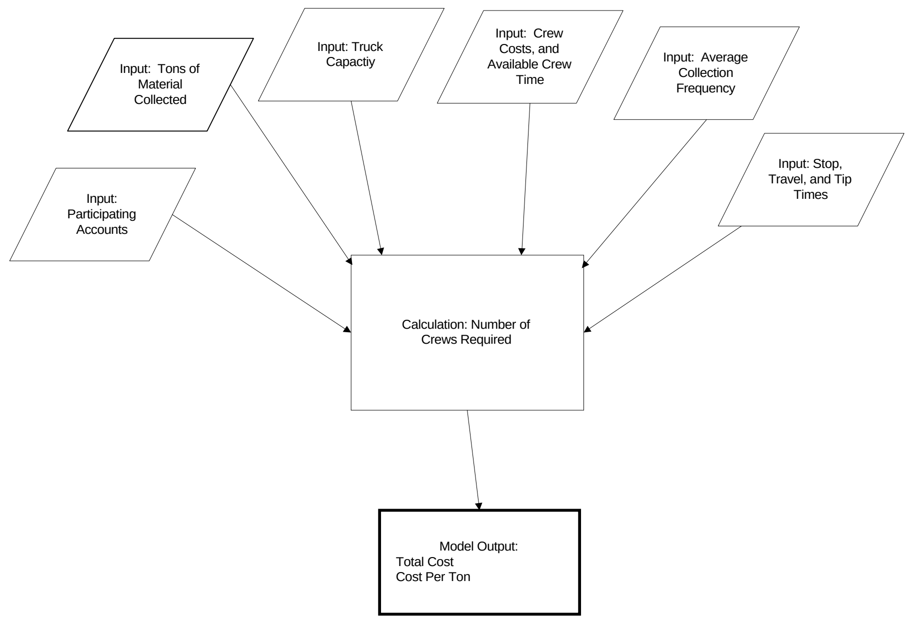
One basic procedure, described below, was used to estimate collection costs for waste streams collected from customers using dumpsters and large containers only:

- Multi-family garbage
- Multi-family recycling
- Commercial garbage
- Commercial food waste

Relatively few scenarios were modeled, compared to the single-family collection cost estimates, because neither co-collection nor radically different frequencies were considered. Because of the large average weight per set-out for these collection programs, co-collection does not result in the large savings possible with single-family accounts. Also, it was assumed that frequency of collection cannot be significantly reduced due to space constraints, and due to legal minimum service requirements for garbage collection. For these four waste streams, the only parameters changed for different scenarios were recycling options, participation rates, and material flows (tip locations).

An overview of the model is shown in Figure 2.

Figure 2: Multi Family and Commercial Collection Model



<u>Collection Model Inputs and Parameters</u>

The estimated collection cost for a given scenario depends on many of the same basic factors as described for the single family model:

- Tons collected
- Number of participating accounts
- Collection frequency
- Estimated stop, travel, and tip times
- Truck capacity
- Crew cost, and time available for collection

<u>Material tons</u>*:* This is the total annual tons to be collected by a fleet. The models do not include the specific composition of each of the streams. Because there are fewer opportunities for changes in these collection systems (as compared to the single family system), less complexity of the model was needed.

<u>Participating accounts</u> The base number of accounts in each program is entered, and it is assumed that all accounts receive the collection service at every opportunity. These customers do not set out containers at the curb; the collector goes to the account location and empties whatever is in the container.

One additional factor that was considered here for the commercial sector is that one account often consists of several businesses. Many businesses share the same building or adjacent buildings, and therefore share garbage service. For future projections, it was assumed that the current statistic of 3.3 businesses per average garbage account would continue. When modeling commercial foodwaste collection, fewer businesses per account were assumed, because it is not likely that food-waste generating businesses will be as clustered as businesses in general.

Collection frequency: The minimum garbage collection frequency allowable (by law) is weekly. Currently, multi-family and commercial customers have selected a service combination of container size and collection frequency that best suits their needs. Garbage is collected as frequently as daily for large generators with limited area for dumpsters. Multifamily recycling collection frequency ranges from weekly to monthly. For this modeling effort, the current average container sizes and service frequencies were used as a starting point[4]. For scenarios that significantly reduced garbage tonnage, the collection frequency was reduced to give the same average set-out weight, which implies the same container size. This assumes that accounts will reduce their frequency of service and keep their container size, as opposed to keeping their frequency of service and reducing their container size. For foodwaste collection, twice a week collection is assumed, due to the extremely putrescible nature of the material. For multi-family recycling, the current standard of every-other-week service is used.

Stop, travel and tip times: The baseline status quo for drive, stop and tip times was obtained empirically, by timing collection crews in action, and from scalehouse transaction records. This baseline was modified for each run, depending on how participation, average set-out weight, type of container, or number of containers per account differed from the status quo. GIS travel time estimates, as described above, were used for new scenarios.

Truck capacity: The current average full-truck weights were used as input to the model. (This information came from transfer station scale house transaction records). For garbage and foodwaste, a typical truck holds eight tons, and for recycling, six tons.

Crew Cost and Time Available for Collection The crew cost estimates used by SPU were developed by Ecodata as part of earlier work done to assess opportunities for cost savings (Stevens, 1994 and 1997). (Crew costs components are described in the single-family section above).

The daily crew time available for collection must take into account time allowed for other routine activities: equipment checks, breaks, wash-up, and the time to drive from and back to the base of operations at the beginning and end of each day.

How the Model Works

The model performs a series of calculations similar to that done in the single-family model. Using annual tons collected, numbers of accounts served, and average collection frequency, the average weight picked up at each account is calculated, and the number of stops made per year. The number of stops needed to fill a truck is determined, and the time required for a crew to collect one full load. The load time is the sum of the necessary number of individual account stop times and travel times to give a full load, plus the round trip cycle time to dump that load at a transfer station. The model then determines how many full and partial loads each crew can complete in their daily available collection time, and from that, the total daily number of accounts that are served by one crew. From this, the model calculates how many crews are needed to collect from all of the accounts.

Collection Cost Model Output

- ***Number of crews required.*** This is the number of crews needed, on average, to provide the indicated collection services to the designated number of accounts.
- ***Annual collection cost.*** The annual total cost of providing the specified collection service to all the accounts is equal to the number of crews required multiplied by the annual crew cost.
- ***Cost per ton.*** Each spreadsheet calculates this output for its customer/material combination. It is equal to the total annual collection cost divided by the annual tons collected.

USING THE RESULTS

[4] Current multi-family statistics were obtained from the Utility's billing system (number of accounts) and transfer station records (tons). Statistics on commercial customers were obtained from the service companies annual filings with the Washington State UTC (Utilities and Transportation Commission,) as included in Stevens (1997).

Model results can be used in two ways: in an absolute sense, meaning as actual estimates of costs, or in a relative sense, meaning to compare the results of various scenarios with each other.

In order that the model would provide the most accurate costs estimates possible, with the intent of their being valid in the absolute sense, SPU "calibrated" the model inputs for the status quo single family collection. By calibration, it is meant that initial estimates or approximations of the various input parameters (described above) were incrementally adjusted as necessary until the "crews required" output of the model matched the number of crews actually used. These calibrated inputs were then used as the baseline.

SPU used the collection cost models to:

- estimate the total costs of collection service packages,
- explore the impacts of isolated changes to a specific collection program, such as adding new materials to the recycling program, changing yardwaste collection frequency, changing container and sorting requirements, or utilizing new tip locations,
- investigate the impacts of participation rates on cost,
- estimate costs for completely new programs, and
- explore collection parameters to identify the greatest opportunities for cost savings.

For comparing program costs, it is critical that the inputs for the various scenarios are <u>internally consistent</u>, meaning that they make sense compared to each other. For example, the "drive time" input would necessarily have to be less for a collection scenario with a greater stop density as compared to another scenario, and the "stop time" input would be less for a collection scenario requiring the pickup of one container at each stop as compared to a scenario requiring the pickup of two containers.

For example, one scenario that SPU considered was co-collection of foodwaste and garbage in a dual packer truck. This would entail the collection of a small container of foodwaste along with the standard container of garbage. SPU had conducted a foodwaste collection pilot and from this had estimates for participation rates and set-out weights. However, a measure of the stop time required to empty two containers was not available. An estimate for this was made, based on the status quo time to empty a single garbage container, with a small additional time increment added for the second container.

When exploring new program concepts there is necessarily some uncertainty in the results. SPU employed <u>sensitivity analyses</u> to determine the extent to which model results would change when considering reasonable ranges of values for the less-certain inputs. By sensitivity analysis, it is meant that a single input variable for one scenario is varied while all others are kept constant, and the resulting range of output is recorded. For example, for Seattle, the status quo average household stop time to pick up one container of garbage is 18 seconds. For the scenario requiring pickup of two containers, presented above, a stop time of 22 seconds was estimated, and sensitivity analysis was done for the range of 20 to 25 seconds. The collection cost estimate of $83.51/ton (for 22 seconds) varied from $80.55 to $91.82 for the range of stop time considered. These numbers are presented to illustrate the use of sensitivity analysis. The base factors will be unique for each jurisdiction, and accurate estimation of these is critical.

SPU considered the range of results from the sensitivity analyses in determining at what level cost differences were significant. The user of the model may also utilize sensitivity analysis to determine which variables are particularly influential on the results, and direct additional resources to improving the quality of data for these inputs.

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