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Estimation and assessment of cost allocation models for main transit systems operating in Cairo

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This paper reviews the main characteristics of the provision of urban transit systems in Cairo, namely buses, minibuses, river buses, trams and surface metros, all being currently operated by Cairo Transport Authority (CTA). It presents some generic types of indicators to compare and assess the performance of the five main urban transit systems provided by CTA. The CTA budget plan for the Financial Year 96/97 is reviewed. The absence of any form of cost modelling as an integral part of CTA budget plans is identified. Here, an attempt is made to develop cost models for the main urban transit systems operated by CTA. Four generic approaches for estimating cost models for transit services are comparatively reviewed, namely the causal factor, cost allocation, regression and temporal variation methods. Cost allocation methods are particularly applied in this research to estimate different cost models for the main transit systems operated by CTA. These models are meant to assist in predicting and showing the relative magnitude of expected changes in various cost categories, resulting from systems/services expansion or down-sizing for the transit modes operated by CTA. The development of such models is thought to contribute in raising the cost consciousness in CTA with the ultimate benefit of maximizing system efficiency.

1. Introduction

Cairo is one of the most densely populated cities in the Middle East with ~12 million capita and an area of ~214 km^2. Public transport systems represent the backbone for the mobility of urban poor in Cairo. These systems have a strong impact on the Egyptian economy, on people's daily life and on their environment. The city suffers from an acute public transport problem, where supply cannot meet the increasing demand, levels of service are deteriorating and traffic congestion causes increasing delay, stress and irritation for masses using public transport systems.

Transit systems in Cairo include buses, minibuses, river buses, trams and surface metros, all being currently provided by Cairo Transport Authority (CTA) and its subsidiary Greater Cairo Bus Company (GCBC). In addition, an underground metro system was open since 1989 and is being operated by a separate unit affiliated to the Egyptian Railways Authority. This paper reviews the main characteristics of the provision of urban transit systems in Cairo and presents some generic type of

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indicators to compare and assess the performance of the five main urban transit systems.

The CTA budget plan for the Financial Year 96/97 is also reviewed. The absence of any form of cost modelling as an integral part of CTA budget plans is identified. Herein, an attempt is made to utilize generic methods to develop cost models for the main urban transit systems.

Four generic approaches for estimating cost models for transit services are comparatively reviewed. These approaches include the causal factor, cost allocation, regression method and the temporal variation method. The cost allocation method is employed to develop cost allocation models for the four main transit systems operated by CTA. These could assist transit decision-makers in predicting and showing the relative magnitude of expected changes in various cost categories, resulting from systems/services expansion or downsizing of transit modes. The development of such models is thought to contribute to raising cost consciousness in CTA with the ultimate benefit of maximizing system efficiency.

2. Characteristics of urban transit systems in Cairo

The state-owned CTA provides the bus, tram, minibus, riverbus and what is known as Heliopolis Surface Metro services. The main organizational components constituting CTA include CTA headquarters, operational garages, maintenance and repair workshops, vocational and management training centres, and, finally, CTA subsidiary company known as GCBC. Transit services to the Greater Cairo area are provided through a network of 338 bus lines, 62 minibus lines, 16 tram lines, nine riverbus lines, six metro lines as well as 117 long-distance bus lines operated by GCBC. It should be noted that these figures portray the 95/96 operation planning (CTA 1996a). These might have been slightly changed since then. It should also be noted that the Heliopolis Surface metro had been affiliated as one of CTA transit systems since 1992.

In addition, CTA operates four central bus maintenance and repair workshops and a steel moulding factory. Training is a vital component of CTA activities. This is portrayed in CTA owning three training centres, the first for operation and technical training, the second for vocational training and the third for management training.

The operational characteristics of CTA transit systems are detailed in table 1. It shows the dominance of bus operation in every aspect followed by the minibus system, the tram system, the surface metro and, finally, the riverbus system. In addition, three performance indicators are portrayed at the end of table 1. The first indicator shows a comparison of actual daily carrying capacities per unit for the different systems. At one end, it is shown that a Heliopolis metro train carries on average 2786 passengers per day, a tram train, 1998 passengers per day, a bus, 1462 passengers per day, a minibus, 667 passengers per day, while at the other end a riverbus carries on average 435 passengers per day. These are considered as high carrying capacities.

The second indicator portrays the overstaffing problem, where an average of 16.7 employees are staffed for each bus, and an average of 167.6 employees are staffed for each Heliopolis Metro Train. These figures demonstrate the acute problem of overstaffing that exists in CTA. This overstaffing problem has a dramatic effect on raising the operation cost of these systems. Finally, the last indicator shows the average speeds for each of the five modes. Average speeds are very low. This can be mainly attributed to the severe traffic congestion that exists in Cairo.

Table 1. Operational characteristics of CTA transit systems*.

Mode	Travelled-km	Operable hours	Operable vehicles	Seated capacity	Seated and standing capacity	Ticket passengers	Employees	Passengers/ vehicle/day	Employees/ vehicle	Average speed (km/h)
Bus	188541286	10038471	651435	33	100	952454000	29860	1462	16.7	17.5
Minibus	42030518	2586796	181433	25	25	121046000	3740	667	7.5	15.2
Riverbus	765533	82674	7140	140	140	3106000	431	435	22	9.3
Tram	5000136	378586	24809**	76	324	49562000	3527	1998	51.9	13.2
Sub-total	236337473	13086527	864817	274	589	1126168000	37558			
Heliopolis Metro	1294919	74561	6406***	144	534	17844000	2941	2786	167.6	17.4
Total	237632392	13161088	871223	418	1123	1144012000	40499			

*Source: *CTA Statistical Report of Operational Achievements for Financial Year 95/96*.

**An operable vehicle for tram represents a typical tram train consisting of two coaches.

***An operable vehicle for Helipolis Metro represents a typical metro train consisting of three coaches.

The CTA annual budget is mainly based on the operation plan. Operation expenses of previous years are considered and updated to include extra requirements of the current year as well as to take price changes and inflation rates into consideration while estimating supply prices. In addition, expected raises are considered while estimating wages. Three budget plans are prepared within CTA, the first is an aggregate budget plan combining the operation requirements of bus, minibus, riverbus and tram systems operation, the second is a separate budget plan for the Heliopolis Surface Metro, and the third is also a separate budget plan for the long-distance bus services provided by GCBC. However, no cost-estimating models exist in all of the three budget plans.

3. Cost modelling approaches

In most transport operation organizations, cost models represent an essential ingredient of budget plans. Cost models, with varying sophistication, can serve the following functions:

- Enhance cost awareness.
- Assist in predicting expected magnitudes of cost changes.
- Serve as major service changes planning tools.
- Assist in the comparison, monitoring and evaluation of cost performance of individual garages/routes/times and service types.
- Offer formulae for comparing cost bids of rival firms in case of privatization of transit services.
- Offer formulae for comparing subsidy levels for different garages/routes/times and types of services.
- Assist in better presentation of budgets.
- Serve as financial planning tools.

The classical literature dealing with cost models in the transit industry identifies four generic approaches for developing cost models for transit services. These include causal factor, cost allocation, regression and temporal variation methods (Booz, Allen & Hamilton 1981, 1984, Savage 1988, 1989). It is crucial to note that these approaches are utilized to develop models that consider only the annual operating cost as opposed to capital costs.

3.1. *Causal factor models*

In causal factor models, total costs are computed as the summation of quantities of resource requirements such as tyres, fuel, oil, spare parts, drivers' hours, each multiplied by its respective current unit cost value (Booz, Allen & Hamilton 1981). Resources requirements are taken from estimates made for the planned future service. Unit cost values are assumed to be the prevailing market price for each resource. This computation can be presented by the following equation:

$$C = \sum_{(i=1)}^{(i=n)} Q_{(i)} * UC_{(i)}$$

where C = cost, Q = quantity, UC = unit cost and i = item considered (i = 1, . . ., n, where n = number of items considered).

3.2. *Cost allocation models*

Several types of cost allocation models can be developed. These vary in their sophistication and, hence, potential utilization (Booz, Allen & Hamilton 1981). At one end of the spectrum are average cost allocation models. The basic principle of such models is to allocate costs of all resource requirements to a single system operating output such as travelled-km, operable hours, or operable vehicles, etc. Thus, average cost allocation models can take any of the following forms:

$$C = UC_{TK} * TK$$

$$C = UC_{OH} * OH \qquad C = UC_{OV} * OV$$

where UC_{TK} = unit cost per travelled-km, TK = number of travelled-km, UC_{OH} = unit cost per operable hour, OH = number of operable hours, UC_{OV} = unit cost per operable vehicle and OV = number of operable vehicles.

At the middle of the spectrum are what are known as fully cost allocation models. The basic principle of such models is to assign costs of item by item in the list of resource requirements to one or more of a selected set of system operating outputs. A typical representative set of system operating outputs includes travelled-km, operable hours and operable vehicles. The fully cost allocation model can take the following form:

$$C = UC_{TK} * TK + UC_{OH} * OH + UC_{OV} * OV$$

A classical application of the fully cost allocation model is known as the Birmingham model (Simpson & Curtin 1977). Other recent applications reported in the US literature are two comprehensive studies describing in detail the development of fully cost allocation models for bus and rail transit systems in the US (Miller 1991, KPMG 1992).

At the end of the spectrum are what can be entitled as differentiative fully cost allocation models. The basic principle of such models is to assign costs, differentiated by type, of item by item in the list of resource requirements to one or more of a selected set of system operating outputs. Costs can be either differentiated according to inputs, or activities or on the basis of temporal variation (White 1995). Generic activities identified by KPMG (1992) include operation, vehicle maintenance, non-vehicle maintenance, administration and general. On the other hand, costs classified on the basis of temporal variation include variable costs, semivariable costs and fixed costs (White 1995).

As previously stated for the fully cost allocation models, a typical representative set of system operating outputs includes travelled-km, operable hours and operable vehicles. A fully cost allocation model differentiated in accordance with temporal variation can take the following form:

$$VC = UVC_{TK} * TK + UVC_{OH} * OH + UVC_{OV} * OV$$

$$SVC = USVC_{TK} * TK + USVC_{OH} * OH + USVC_{OV} * OV$$

$$FC = UFC_{TK} * TK + UFC_{OH} * OH + UFC_{OV} * OV$$

where VC = variable costs, SVC = semivariable costs, FC = fixed costs, UVC_{TK} = unit variable cost/travelled-km, UVC_{OH} = unit variable cost/operable hour, UVC_{OV} = unit variable cost/operable vehicle, $USVC_{TK}$ = unit semivariable cost/travelled-km, $USVC_{OH}$ = unit semivariable cost/operable hour, $USVC_{OV}$ =

unit semivariable cost per operable vehicle, UFC_{TK} = unit fixed cost per travelled-km, UFC_{OH} = unit fixed cost per operable hour and UFC_{OV} = unit fixed cost per operable vehicle.

Two classical applications of the fully cost allocation model differentiated in accordance with temporal variation are the National Bus Company model and the Merseyside Bus Company model. Both models were developed in the UK (CIPFA 1974, McClenahan and Kay 1975, Taylor 1975).

3.3. *Regression models*

Regression models use a complete set of sample data to estimate coefficients for resource variables that are thought to influence costs. These independent variables can include travelled-km, operable hours, operable vehicles, fleet age and driver's wage. The database for the regression method consists of either cross-sectional data for several systems at one point in time, or time series information that describe changes in a single system over time. A cost regression model can take the following form:

$$C = a_1 * TK + a_2 * OH + a_3 * OV + a_4 X_4 + a_5 X_5 + \dots + c$$

where a_{1-5}, etc. = estimated coefficients showing effect of independent resource variables on system costs, X_{1-5}, etc. = independent resource variables considered to affect system costs and c = constant representing part of cost which is unexplained by considered independent variables.

Classical applications of developing cost regression models for bus transit systems are reported in McGillivray *et al.* (1980), while cost regression models related to rail transit systems are reported in Pozdena and Merewitz (1978) and Viton (1980). Another relatively recent application was reported by Talley and Anderson (1986).

3.4. *Temporal variation models*

It is generally accepted that transit demand and its characteristics varies over time. Transit operators plan their services in accordance with this time-variant demand. Services can differ in terms of quantity and quality. Consequently, these service variations cause cost variations. Temporal variation methods attempt to model and represent these temporal cost variations. The cost adjustment approach basically modifies the conventional cost allocation models' unit cost coefficients to include differences between peak and off-peak operation. Classical applications of this approach are reported in Cherwony and Mundle (1978), Levinson (1978) and Reilly (1977). It can be represented in the following form:

$$PPC = UPC_{TK} * TK + UPC_{OH} * OH + UPC_{OV} * OV$$
$$OPPC = UOPC_{TK} * TK + UOPC_{OH} * OH + UOPC_{OV} * OV$$

where PPC = peak period cost, OPPC = off-peak period cost, UPC_{TK} = unit peak cost per travelled-km, UPC_{OH} = unit peak cost per operable hour, UPC_{OV} = unit peak cost per operable vehicle, $UOPC_{TK}$ = unit off-peak cost per travelled-km, $UOPC_{OH}$ = unit off-peak cost per operable hour and $UOPC_{OV}$ = unit off-peak cost per operable vehicle.

The statistical approach estimates regression models using sample data to relate time-variant input resource components to output measures of transit service disaggregated in accordance with peak/off-peak services. These are then incorporated as one component within the fixed/variable cost allocation models. Classical examples of this approach are the Arthur Anderson model and the London Transport model (McClenahan *et al.* 1978).

The third type of temporal variation methods, known as the resource approach, differentiates and focuses mainly on resource quantities and their costs that are liable to change (vehicles and crews) as a result of service changes over the day or over days of the week. The literature reports the Northwestern model (Morlok *et al.* 1971), which is basically a cost allocation model that takes into account only those expenses expected to change as a result of a service change, i.e. the variable costs. The two most widely known classical examples of this approach are the Bradford model and its matured version known as the Adelaide model (Morgan 1976, 1980). Both models not only follow the fixed/variable cost allocation approach, but also use monthly data to conduct in-depth analysis of cost variations with respect to time and types of services and incorporate these in the cost allocation model. The main difference between the two models is that the Adelaide model uses slightly different produced outputs to represent service changes (Hill *et al.* 1984).

3.5. *Comparison among different methods used for cost modelling*

A comprehensive qualitative comparison of cost modelling methods, sponsored by the US Department of Transport, was reported in Booz, Allen & Hamilton (1981, 1984). This was a two-stage comparison, the first concerned with assessing the models' sensitivity to service change costs, the second representing an expert review panel's assessment of the models' performance against weighted criteria. Considered criteria included simplicity, economy, logic, service sensitivity, component sensitivity, temporal sensitivity, flexibility, range of results, data compatibility, ease of use, adaptability and response time.

During the course of this research, it was thought appropriate to conduct another comparison between these cost allocation methods with the purpose of gaining more insight into the potentialities and restrictions of these models. This is meant to assist in the choice of the cost allocation approaches that would seem more appropriate for application to develop cost models for the different transit systems operated by CTA. Six criteria used for comparison, namely required data, explanatory parameters, cost variation, ability to estimate marginal costs due to service changes, simplicity, accuracy and reliability, level of aggregation and application.

The comparison demonstrates the superiority of temporal variation models in terms of reliability and ability to estimate marginal costs resulting from service changes. The Adelaide model, providing both incremental and allocated cost data, has been adopted in many Australian and New Zealand cities. However, this approach requires a more detailed database than what is commonly available to CTA.

Cost allocation models and particularly disaggregate cost allocation models are not as sensitive as temporal variation models. However, their advantages in terms of data requirements and relative simplicity and ease of use have been demonstrated by other researchers. Therefore, it was decided to develop cost allocation models of varying sophistication for the different transit systems operated by CTA. It is to be noted that in the USA the offering of existing transit routes for tender has required formulae for comparing the cost bids of rival firms. In this respect, the US government has taken the view that bids based on allocated costs are more realistic in the long term than incremental cost bids (Price Waterhouse 1987).

4. Development of a generic algorithm for estimation of cost allocation models

The main objective of this research is to estimate cost allocation models for the four main transit systems operated by CTA. In the process of building these models, a generic algorithm for estimation of cost allocation models was developed. The algorithm is depicted in figure 1. It is mainly composed of four main stages. The following presents a detailed review of these stages.

4.1. *Stage 1: Cost classification*

As previously mentioned, costs can be differentiated in accordance with three generic classifications. The first is in accordance to system required inputs, usually referred to as budget inputs. The second classification differentiates cost items in accordance with system generic activities, usually taken as operation, maintenance, general and administration. The third classification differentiates cost items into generic types of time-variant categories, usually taken as variable, semivariable and fixed costs.

4.2. *Stage 2: Cost allocation (assignment)*

In this stage, costs are allocated to a selected set of generic produced outputs. A typical set includes travelled-km, operable hours and operable vehicles. This cost allocation can be performed using an all or nothing assignment, i.e. assigning all costs of each particular item to a single variable from the selected set of produced outputs. Alternatively a percentage assignment can be conducted, where costs of each particular item are assigned using different percentages to the variables included in the selected set of produced outputs. In all cases, the allocation of costs to produced outputs has to be thought of in a careful manner, taking into consideration the definition of different cost items and their components.

4.3. *Stage 3: Cost aggregation and disaggregation*

This stage simply represents the aggregation and disaggregation of costs to fall in line with the development of alternative cost allocation models. The figure shows the possibility of developing five cost allocation models that vary in their sophistication and detail, these are:

1. Average cost allocation models.
2. Fully cost allocation models.
3. Fully cost allocation models differentiated according to generic activities.
4. Fully cost allocation models differentiated according to temporal variation cost categories.
5. Fully cost allocation models differentiated according to generic activities and further differentiated according to temporal variation cost categories.

4.4. *Stage 4: Estimation of unit costs for produced outputs*

This final stage is basically concerned with the estimation of unit costs for each of the selected produced outputs. For each of the produced outputs, this is done by dividing the overall cost type assigned to this particular output by the quantity of output produced by the system within the period of the analysis.

5. Procedure followed for estimation of cost allocation models for main transit systems operated by CTA

The following is a detailed discussion of steps followed to apply the previously presented generic algorithm to estimate various cost allocation models for the four main transit systems operated by CTA.

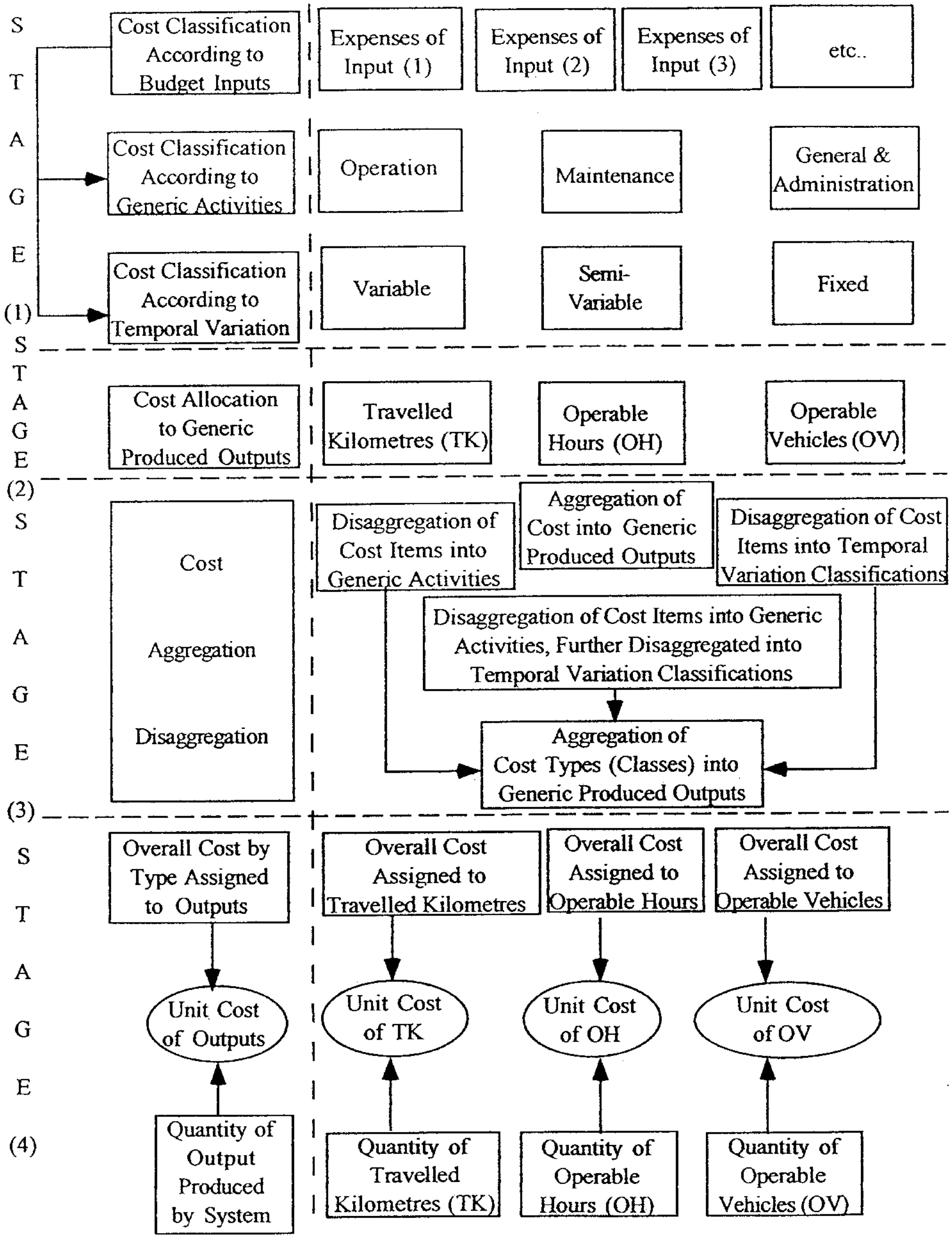

Figure 1. Algorithm for estimation of cost allocation models.

5.1. *Step 1*

Classification of cost elements (items) as detailed in CTA recent budget plan (CTA 1996b) was identified. Each of the 87 budget inputs represents an aggregation of the particular cost element for the four main transit modes operated by CTA, namely buses, minibuses, river buses, and trams. The first 68 cost items, represent basic material requirements. Cost items 69 – 74 represent the aggregation of CTA staff salaries in accordance to: generic activities (i.e. operation, maintenance, general and administration); and time variability (i.e. variable, semivariable, fixed). This aggregation was obtained as a result of a thorough item by item review of position titles of CTA staff as presented in CTA budget plan, categorization of these position titles, and accumulation of salaries into groups 69 – 74. The rest of the cost items (75 – 87), represent other staff-related cost items such as bonuses, incentives, benefits, subsidiaries, insurances, etc., as stated in CTA budget plan. It is to be noted that within the CTA budget plan there is a separate budget for the surface metro. This is presented as described by items 1 – 68 as well as 69 – 74. However, there is not enough detailed data to allow the classification and aggregation of surface metro staff salaries as conducted for the other four modes. For consistency purposes, the surface metro was excluded from this research.

5.2. *Step 2*

The definition of each cost input as stated in CTA budget was examined. Based on this examination as well as on the experience of the authors and advice of experts, judgements were made regarding the classification of each cost input according to the most plausible generic activity generating this cost item. As previously stated, three generic activities were considered, namely operational, maintenance, general and administration. It should be noted that items such as fuel, oil, lubricants, ticket printing, vehicle insurance, licensing, taxes, etc. are considered as operation related. While, items such as spare parts, equipment maintenance and depreciation, etc. are considered as maintenance related. Finally, items related to inventory, marketing, publicity, telephone, telegram, mail, staff related expenses, etc. are considered under general and administration.

5.3. *Step 3*

The definition of each cost input as stated in CTA budget was re-examined. Based on this re-examination, the previous classification according to generic activities as well as on the experience of the authors and advice of experts, judgements were made regarding the classification of each cost input according to their most plausible basis of temporal variation. As previously stated, three temporal variation classes were considered, namely variable, semivariable, and fixed. It is to be noted that most of the operation related items are considered as variable costs, while those items that are maintenance related are considered as variable or semivariable costs. Finally, those items that are general and administration related are mainly considered as fixed costs.

5.4. *Step 4*

The definition of each cost input as stated in CTA budget was examined for the third time. Based on this examination, previous classifications in accordance to generic activities and temporal variation classes, as well as on the experience of the authors and advice of experts, judgements were made regarding the allocation of each cost input into the most plausible produced output. As previously mentioned, three generic produced outputs were considered, namely travelled-km, operable hours and operable vehicles. It is to be noted that the cost assignment (allocation) into generic produced outputs was based on an all-or-nothing assignment with operation variable cost items being mainly assigned to travelled-km, maintenance semivariable cost items mainly assigned to operable hours and general/administration fixed cost items mainly assigned to operable vehicles.

5.5. *Step 5*

As previously mentioned, CTA annual budget is aggregated over four transit modes, namely bus, minibus, tram and riverbus. Therefore, budget dismantling into four separate budgets was warranted. This would mean determining the share of each budget component among each of the four considered transit modes. This dismantling was performed using five generic cost weighting factors. These weighting factors were carefully thought of, and selected for each cost input, so as to represent:

- the modal proportionality with respect to generic output produced as a result of consumption of the particular cost input; and
- the modal proportionality with respect to resource inputs and variables affecting the rate of consumption of the particular cost input.

Each of the weighting factors consists of two multiple factors. The general form of the cost weighting factors is

$$\text{Cost Weighting Factor}_{(M)} =$$

$$\text{Output Weighting Factor}_{(M)} * \text{Cost Consumption Weighting Factor}_{(M)}$$

$$M = \text{Particular Transit Mode (i.e. Bus, Minibus, Riverbus, Tram)}$$

The five utilized cost weighting factors were computed as follows:

1. travelled-km Weighting $\text{Factor}_{(M)}$ * Seated Capacity Weighting $\text{Factor}_{(M)}$
2. operable hours Weighting $\text{Factor}_{(M)}$ * Seated and Standing Capacity Weighting $\text{Factor}_{(M)}$
3. operable vehicles Weighting $\text{Factor}_{(M)}$ * Seated and Standing Capacity Weighting $\text{Factor}_{(M)}$
4. operable vehicles Weighting $\text{Factor}_{(M)}$ * Passengers/Vehicle Weighting $\text{Factor}_{(M)}$
5. operable vehicles Weighting $\text{Factor}_{(M)}$ * Employee/Vehicle Weighting $\text{Factor}_{(M)}$

Values of these five types of cost weighting factors for the four considered transit modes are listed in table 2.

5.6. *Step 6*

From this step onwards, the four budgets representing the four transit systems are dealt with separately. This step is concerned with summing pools of cost items

Table 2. Cost weighting factors among CTA transit modes.

	CTA Modes			
Cost weighting factors	Bus	Minibus	Riverbus	Tram
Travelled-$km_{(i)}$ *seated $capacity_{(i)}$	0.8	0.14	0.01	0.05
Operable $hours_{(i)}$ *seated and standing $capacity_{(i)}$	0.83	0.06	0.01	0.1
Operable $vehicles_{(i)}$ *seated and standing $capacity_{(i)}$	0.83	0.06	0.01	0.1
Operable $vehicles_{(i)}$ *passengers/$vehicle_{(i)}$	0.85	0.107	0.003	0.04
Operable $vehicles_{(i)}$ *employees/$vehicle_{(i)}$	0.8	0.1	0.01	0.09

grouped together in accordance with generic produced outputs. The outcome of this step would give three cumulative cost figures, namely:

- overall cost resulting from producing the particular transit system travelled-km;
- overall cost resulting from producing the particular transit system operable hours; and
- overall cost resulting from producing the particular transit system operable vehicles.

These are used in developing the average cost allocation models and the fully cost allocation models.

5.7. *Step 7*

This step is mainly concerned with disaggregating cost items in accordance with cost classifications stated in steps 2 – 4, namely:

- cost disaggregated into three classes representing generic activities (operational, maintenance, general and administration);
- cost disaggregated into three classes representing temporal variation (variable, semivariable and fixed); and
- cost disaggregated into nine classes representing classes of generic activities, which are further disaggregated into classes of temporal variation.

5.8. *Step 8*

This is mainly concerned with aggregating cost items (classified in accordance with generic activities, or in accordance with temporal variation, or in accordance with generic activities and temporal variation) in accordance with the generic produced outputs causing the incurring of these cost items, i.e. the outcome of this step would give the following types of cumulative costs.

$$\mathrm{Cost}^{(GPO)}_{(GA)}$$

where GA= Generic Activities (Operation, Maintenance, General and Administration)
GPO= Generic Produced Outputs (travelled-km, operable hours, operable vehicles).

These are used in developing the fully cost allocation models differentiated according to generic activities.

$$\mathrm{Cost}^{(\mathrm{GPO})}_{(\mathrm{TV})}$$

where TV= Temporal Variation Classes (Variable, Semi-Variable, Fixed).

These are used in developing the fully cost allocation models differentiated according to temporal variation cost categories.

$$\mathrm{Cost}^{(\mathrm{GPO})}_{(\mathrm{GA})(\mathrm{TV})}$$

These are used in developing the fully cost allocation models differentiated according to generic activities and further differentiated according to temporal variation cost categories.

5.9. *Step 9*

This final step is basically concerned with the estimation of unit costs (calibration factors) for each of the selected produced outputs for each of the five cost allocation models. The quantities of generic produced outputs, within the period of the analysis, are first defined, i.e. number of travelled-km, number of operable hours and number of operable vehicles. Then, for each cost allocation model, the overall summation of cost types (see steps 6 and 8) are divided by their associated quantity of output produced by the system, and unit cost of the output is estimated.

6. Cost allocation models for CTA transit systems

As a result of following the above detailed algorithm, different types of cost allocation models with different sophistication levels were estimated for the main transit systems operated by CTA. All these models share their functionality of generic produced outputs. The following subsections discuss these cost allocation models.

6.1. *Average cost allocation models for CTA transit systems*

In these models, total costs are allocated to a single representative produced output such as travelled-km or operable hours or operable vehicles. Average cost allocation models for each of the four CTA transit systems were estimated. These are shown in table 3. For the four modes, it is obvious that sensitivity of cost with respect to changes in operable vehicles is the highest, followed by operable hours and km of travel. This is logically expected as changes in the number of operable vehicles entail changes in most items of costs including fixed, semivariable and variable costs, while changes in the number of operable hours entail changes in semivariable and variable costs and, lastly, changes in km of travel entail mainly changes in variable costs.

Table 3. Average cost allocation models for CTA transit systems.

	Average cost	Allocation	Models
Mode	Based on travelled-km	Based on operable hours	Based on operable vehicles
Bus	Cost= 2.95 (TK)	Cost= 55.46 (OH)	Cost= 854.62 (OV)
Minibus	Cost= 1.28 (TK)	Cost= 20.81 (OH)	Cost= 296.74 (OV)
Riverbus	Cost= 10.37 (TK)	Cost= 96.06 (OH)	Cost= 1112.32 (OV)
Tram	Cost= 14.44 (TK)	Cost= 190.69 (OH)	Cost= 2909.99 (OV)

In addition, it can be shown from the table that cost sensitivity is directly related to the size of the particular operating unit, whereas for example, a unit change in travelled-km by the tram is expected to cause incurring of an extra 14.44 Egyptian Pounds (LE) (LE1 = US$3.4) while at the other end of the spectrum, a unit change in travelled-km by the minibus is expected to cause incurring of an extra LE1.28.

6.2. *Fully cost allocation models of input based cost categories for CTA transit systems*

The second type of cost allocation models, known as fully cost allocation models of input based cost categories, looks at the list of inputs and allocates the cost of each input over a set of representative and generic produced outputs, usually taken as travelled-km, operable hours and operable vehicles. Fully cost allocation models estimated for the four CTA transit systems are shown in table 4. It shows the cost sensitivity with respect to unit changes in the three generic explanatory variables. Again, it is shown that cost sensitivity with respect to changes in operable vehicles is the highest, followed by cost sensitivity with respect to changes in operable hours, and followed by cost sensitivity with respect to changes in travelled-km. This is logically expected as changes in operable vehicles entail changes in most types of costs including fixed, semivariable and variable costs, while changes in operable hours entail changes in semivariable and variable costs and lastly changes in travelled-km entail changes in only variable costs. In general, the models, for the four modes, show similar trends in that on average the percentage contribution of costs resulting from the production of:

- travelled-km is ∼14%;
- operable hours is ∼21%; and
- operable vehicles is ∼64%.

This percentage ranking is expected as costs resulting from the production of operable vehicles would include such costs as depreciation and all staff related costs. These are significant cost items. However, these big differences between costs resulting from the production of operable vehicles versus the other two types of costs signifies such problems as high staff related costs resulting from overstaffing. In addition, it can be observed that costs resulting from the production of travelled-km are less than those costs resulting from the production of operable hours. This signifies the problem of high maintenance requirements resulting from the ageing of

Table 4. Fully cost allocation models of input-based cost categories for CTA transit systems.

Mode	Fully cost allocation models of input-based cost categories
Bus	Cost= 0.3 (TK)+ 13.75 (OH)+ 557.09 (OV) (10%)+ (24.8%)+ (65.2%)
Minibus	Cost= 0.22 (TK)+ 3.438 (OH)+ 195.9 (OV) (17.45%)+ (16.52%)+ (66.03%)
Riverbus	Cost= 1.25 (TK)+ 19.26 (OH)+ 755.12 (OV) (12.07%)+ (20.04%)+ (67.89%)
Tram	Cost= 2.22 (TK)+ 44.56 (OH)+ 1781.99 (OV) (15.39%)+ (23.37%)+ (61.24%)

existing fleets and causing high maintenance costs related to operable hours. In addition, it can be shown from the table that cost sensitivity is directly related to the size of the particular operating unit, whereas for example, a unit change in operable hours by the tram is expected to cause incurring of an extra LE44.56, while at the other end of the spectrum, a unit change in operable hours by the minibus is expected to cause incurring of an extra LE3.44.

6.3. *Fully cost allocation models of activity based cost categories for CTA transit systems*

The third type of cost allocation models, can be referred to as fully cost allocation models differentiated according to generic activities, namely operational, maintenance, general and administration. These models allocate each cost item, classified in accordance with generic activities, over the same set of representative generic produced outputs. A total of 12 models were estimated, three for each of the four considered CTA transit systems. These are depicted in table 5.

The models reveal the dominance of operating costs, where this type of costs constitute ∼49 – 55% of the total cost for the four CTA transit systems, whereas for example the share of minibus operation costs being relatively the lowest, while the share of riverbus operation costs being relatively the highest. On the other hand, maintenance costs constitute ∼20 – 27% of the total cost, whereas for example the share of minibus maintenance costs being relatively the lowest (∼19.99%), while the share of tram maintenance costs being relatively the highest (∼27.16%). Similarly,

Table 5. Fully cost allocation models of activity-based cost categories for CTA transit systems.

Mode	Fully cost allocation models of activity-based cost categories
Bus	Operation cost= 0.3 (TK)+ 0 (OH)+ 336.3 (OV) (10%)+ (0%)+ (39.4%)
	Maintenance cost= 0 (TK)+ 13.75 (OH)+ 17.8 (OV) (0%)+ (24.8%)+ (2.1%)
	General and administration cost= 0 (TK)+ 0 (OH)+ 203 (OV) (0%)+ (0%)+ (23.7%)
Minibus	Operation cost= 0.22 (TK)+ 0 (OH)+ 94.26 (OV) (17.45%)+ (0%)+ (31.77%)
	Maintenance cost= 0 (TK)+ 3.438 (OH)+ 10.29 (OV) (0%)+ (16.52%)+ (3.47%)
	General and administraion cost= 0 (TK)+ 0 (OH)+ 91.38 (OV) (0%)+ (0%)+ (30.79%)
Riverbus	Operation cost= 1.25 (TK)+ 0 (OH)+ 476.75 (OV) (12.07%)+ (0%)+ (42.86%)
	Maintenance cost= 0 (TK)+ 19.26 (OH)+ 16.75 (OV) (0%)+ (20.04%)+ (1.51%)
	General and administration cost= 0 (TK)+ 0 (OH)+ 261.63 (OV) (0%)+ (0%)+ (23.52%)
Tram	Operation cost= 2.08 (TK)+ 0 (OH)+ 1080.99 (OV) (14.39%)+ (0%)+ (37.15%)
	Maintenance cost= 0.14 (TK)+ 44.56 (OH)+ 81.14 (OV) (1%)+ (23.37%)+ (2.79%)
	General and administration cost= 0 (TK)+ 0 (OH)+ 619.85 (OV) (0%)+ (0%)+ (21.3%)

general and administration costs constitute $\sim 21-31\%$ of the total cost, where the share of tram general and administration costs is the lowest in relative terms ($\sim$21.3%), while the share of minibus general and administration costs is the highest in relative terms ($\sim$30.79%). A wider variability, in relative terms, is noted in the percentage share of general and administration costs across the four CTA transit modes.

Previous conclusions drawn in previous subsections can be also deduced in this subsection. In addition, it is obvious from the models that operation costs resulting from the production of operable vehicles is significant. This can be attributed to depreciation costs as well as to overstaffing of operation staff. On the other hand, maintenance costs resulting from the production of operable vehicles is very minor, which seems to indicate that there is no problem of overstaffing of maintenance staff. However, the problem of ageing fleet causes an increase in maintenance requirements and, hence, maintenance costs related to operable hours.

6.4. *Fully cost allocation models of temporal variation based cost categories for CTA transit systems*

The fourth type of cost allocation models, can be referred to as fully cost allocation models differentiated according to temporal variation cost categories, namely variable, semivariable, and fixed cost categories. These models allocate each cost item, classified in accordance with temporal variation cost categories, over the same set of representative generic produced outputs. A total of 12 models were estimated, three for each of the four considered CTA transit systems (table 6).

Table 6. Fully cost allocation models of temporal variation-based cost categories for CTA transit systems.

Mode	Fully cost allocation models of temporal variation-based cost categories
Bus	Variable cost= 0.3 (TK)+ 13.74 (OH)+ 0.31 (OV) (10%)+ (24.78%)+ (0.04%)
	Semivariable cost= 0 (TK)+ 0.008 (OH)+ 48.3 (OV) (0%)+ (0.02%)+ (5.66%)
	Fixed cost= 0 (TK)+ 0 (OH)+ 508.5 (OV) (0%)+ (0%)+ (59.5%)
Minibus	Variable cost= 022 (TK)+ 3.436 (OH)+ 0.14 (OV) (17.45%)+ (16.51%)+ (0.05%)
	Semivariable cost= 0 (TK)+ 0.002 (OH)+ 28.4 (OV) (0%)+ (0.01%)+ (9.57%)
	Fixed cost= 0 (TK)+ 0 (OH)+ 167.38 (OV) (0%)+ (0%)+ (56.41%)
Riverbus	Variable cost= 1.25 (TK)+ 19.24 (OH)+ 0.09 (OV) (12.07%)+ (20.03%)+ (0.01%)
	Semivariable cost= 0 (TK)+ 0.012 (OH)+ 64.86 (OV) (0%)+ (0.01%)+ (5.83%)
	Fixed cost= 0 (TK)+ 0 (OH)+ 690.17 (OV) (0%)+ (0%)+ (62.05%)
Tram	Variable cost= 2.22 (TK)+ 44.53 (OH)+ 0.43 (OV) (15.39%)+ (23.36%)+ (0.01%)
	Semivariable cost= 0 (TK)+ 0.03 (OH)+ 158.26 (OV) (0%)+ (0.01%)+ (5.45%)
	Fixed cost= 0 (TK)+ 0 (OH)+ 1623.3 (OV) (0%)+ (0%)+ (55.78%)

The models reveal that variable costs constitutes ~32–39% of the total cost for the four CTA transit systems, whereas for example the share of riverbus variable costs being relatively the lowest, while the share of tram variable costs being relatively the highest. On the other hand, semivariable costs constitute only ~5–10% of the total cost, whereas for example the share of tram semivariable costs being relatively the lowest (~5.46%), while the share of minibus semivariable costs being relatively the highest (~9.58%). The models show the dominance of fixed costs, which constitute ~56–62% of the total cost, where the share of tram fixed costs is the lowest in relative terms (~55.78%), while the share of riverbus fixed costs is the highest in relative terms (~62.05%).

Previous conclusions drawn in previous subsections can be also deduced in this subsection. In addition, it is obvious from the models that variable costs result mainly from the production of operable hours and travelled-km. On the other hand, the models show that semivariable and fixed costs result mainly from the production of operable vehicles.

6.5. *Fully cost allocation models of activity based cost categories disaggregated into temporal variation cost categories for CTA transit systems*

The fifth and most sophisticated type of cost allocation models, can be referred to as fully cost allocation models differentiated according to generic activities and further differentiated according to temporal variation cost categories. These models allocate each cost item, classified according to generic activities and further classified according to temporal variation cost categories, over the same set of representative generic produced outputs. A total of 36 models was estimated, nine for each of the four considered CTA transit systems. Bus and minibus models are depicted in table 7, while riverbus and tram models are depicted in table 8.

These models are at a such level of detail that allows their use in the assessment of changes in various generic types of cost that are expected to result from service changes. Thus, these models can be used as tools to assist in the evaluation of different strategies for improving transit service.

The models reveal that operation variable costs constitute ~10–17% of total costs. This is mainly sensitive to changes in travelled-km. On the other hand, maintenance variable costs constitute ~16–24% of total costs. This is mainly dependent on changes in operable hours. The models show the non-existence of general and administration variable costs.

The models also reveal that operation semivariable costs constitute ~3–6% of total costs. This is mainly sensitive to changes in operable vehicles. On the other hand, maintenance semivariable costs constitute ~0.5–3% of total costs. This is mainly dependent on changes in operable hours. The models show the minor contribution of general and administration semivariable costs. This type of costs constitute only ~0.2–0.4% of total costs.

Finally, the models reveal that operation fixed costs constitute the highest percentage share of total costs, i.e. ~25–38%. This is mainly sensitive to changes in operable vehicles. This is followed by general and administration fixed costs, which constitute ~21–30% of total costs. This is also mainly dependent on changes in operable vehicles. On the other hand, maintenance fixed costs constitute a minor percentage share, only ~0.7–1.3% of total costs. This is also mainly dependent on changes in operable vehicles.

Table 7. Fully cost allocation models of activity-based cost categories disaggregated into temporal variation cost categories for CTA bus and minibus transit systems.

Mode	Fully cost allocation models of activity-based cost categories disaggregated into temporal variation cost categories
Bus	Operation variable cost= 0.3 (TK)+ 0 (OH)+ 0.31 (OV) (10%)+ (0%)+ (0.04%)
	Operation semivariabe cost= 0 (TK)+ 0 (OH)+ 35.7 (OV) (0%)+ (0%)+ (4.18%)
	Operation fixed cost= 0 (TK)+ 0 (OH)+ 300.3 (OV) (0%)+ (0%)+ (35.15%)
	Maintenance variable cost= 0 (TK)+ 13.74 (OH)+ 0 (OV) (0%)+ (24.78%)+ (0%)
	Maintenance semivariable cost= 0 (TK)+ 0.008 (OH)+ 10.08 (OV) (0%)+ (0.02%)+ (1.18%)
	Maintenance fixed cost= 0 (TK)+ 0 (OH)+ 7.71 (OV) (0%)+ (0%)+ (0.9%)
	General and administration variable cost= 0 (TK)+ 0 (OH)+ 0 (OV) (0%)+ (0%)+ (0%)
	General and administration semivariable cost= 0 (TK)+ 0 (OH)+ 2.517 (OV) (0%)+ (0%)+ (0.3%)
	General and administration fixed cost= 0 (TK)+ 0 (OH)+ 200.426 (OV) (0%)+ (0%)+ (23.45%)
Minibus	Operation variable cost= 0.22 (TK)+ 0 (OH)+ 0.14 (OV) (17.45%)+ (0%)+ (0.05%)
	Operation semivariable cost= 0 (TK)+ 0 (OH)+ 18.95 (OV) (0%)+ (0%)+ (6.4%)
	Operation fixed cost= 0 (TK)+ 0 (OH)+ 75.17 (OV) (0%)+ (0%)+ (25.33%)
	Maintenance variable cost= 0 (TK)+ 3.436 (OH)+ 0 (OV) (0%)+ (16.51%)+ (0%)
	Maintenance semivariable cost= 0 (TK)+ 0.002 (OH)+ 8.31 (OV) (0%)+ (0.01%)+ (2.8%)
	Maintenance fixed cost= 0 (TK)+ 0 (OH)+ 1.97 (OV) (0%)+ (0%)+ (0.66%)
	General and administration variable cost= 0 (TK)+ 0 (OH)+ 0 (OV) (0%)+ (0%)+ (0%)
	General and administration semivariable cost= 0 (TK)+ 0 (OH)+ 1.14 (OV) (0%)+ (0%)+ (0.38%)
	General and administration fixed cost= 0 (TK)+ 0 (OH)+ 90.24 (OV) (0%)+ (0%)+ (30.41%)

Previous conclusions drawn in previous subsections can be also deduced in this subsection. In addition, it is obvious from the models that the most dominant cost relations are:

- *First*: fixed operation costs being sensitive to changes in operable vehicles.
- *Second*: fixed general and administration costs being sensitive to changes in operable vehicles.
- *Third*: variable maintenance costs being sensitive to changes in operable hours.
- *Fourth*: variable operation costs being mainly sensitive to changes in travelled-km.

Table 8. Fully cost allocation models of activity-based cost categories diaggregated into temporal variation cost categories for CTA riverbus and tram transit systems.

Mode	Fully cost allocation models of activity-based cost categories disaggregated into temporal variation cost categories
Riverbus	Operation variable cost= 1.25 (TK)+ 0 (OH)+ 0.09 (OV) (12.07%)+ (0%)+ (0.01%)
	Operation semivariable cost= 0 (TK)+ 0 (OH)+ 56.16 (OV) (0%)+ (0%)+ (5.05%)
	Operation fixed cost= 0 (TK)+ 0 (OH)+ 420.5 (OV) (0%)+ (0%)+ (37.8%)
	Maintenance variable cost= 0 (TK)+ 19.24 (OH)+ 0 (OV) (0%)+ (20.03%)+ (0%)
	Maintenance semivariable cost= 0 (TK)+ 0.012 (OH)+ 6.01 (OV) (0%)+ (0.01%)+ (0.54%)
	Maintenance fixed cost= 0 (TK)+ 0 (OH)+ 10.74 (OV) (0%)+ (0%)+ (0.97%)
	General and administration variable cost= 0 (TK)+ 0 (OH)+ 0 (OV) (0%)+ (0%)+ (0%)
	General and administration semivariable cost= 0 (TK)+ 0 (OH)+ 2.69 (OV) (0%)+ (0%)+ (0.24%)
	General and administration fixed cost= 0 (TK)+ 0 (OH)+ 258.93 (OV) (0%)+ (0%)+ (23.28%)
Tram	Operation variable cost= 2.08 (TK)+ 0 (OH)+ 0.43 (OV) (14.39%)+ (0%)+ (0.01%)
	Operation semivariable cost= 0 (TK)+ 0 (OH)+ 107.54 (OV) (0%)+ (0%)+ (3.7%)
	Operation fixed cost= 0 (TK)+ 0 (OH)+ 973.02 (OV) (0%)+ (0%)+ (33.44%)
	Maintenance variable cost= 0.14 (TK)+ 44.53 (OH)+ 0 (OV) (1%)+ (23.36%)+ (0%)
	Maintenance semivariable cost= 0 (TK)+ 0.03 (OH)+ 43.97 (OV) (0%)+ (0.01%)+ (1.51%)
	Maintenance fixed cost= 0 (TK)+ 0 (OH)+ 37.17 (OV) (0%)+ (0%)+ (1.28%)
	General and administration variable cost= 0 (TK)+ 0 (OH)+ 0 (OV) (0%)+ (0%)+ (0%)
	General and administration semivariable cost= 0 (TK)+ 0 (OH)+ 6.75 (OV) (0%)+ (0%)+ (0.23%)
	General and administration fixed cost= 0 (TK)+ 0 (OH)+ 613.11 (OV) (0%)+ (0%)+ (21.07%)

7. Conclusion

This paper reviewed the main characteristics of urban transit systems in Cairo. Transit systems in Cairo include buses, minibuses, river buses, trams, and surface metros all being currently provided by CTA and its subsidiary GCBC. The main organizational components constituting CTA were depicted. The paper presented some generic types of indicators to compare and assess the performance of the five main urban transit systems provided by CTA. The high carrying capacities of CTA transit modes was portrayed. The acute overstaffing problem with its dramatic effects on raising the operation costs of transit systems was demonstrated and the low average running speeds that can be mainly attributed to severe traffic congestion problem was shown. In addition, the paper presented an overview of the underground metro system, which was first opened in 1989 and which is being operated by a separate unit affiliated to the Egyptian Railways Authority.

The CTA budget plan for the Financial Year 96/97 was reviewed. The absence of any form of cost modelling as an integral part of CTA budget plans was identified. In this paper, an attempt was made to utilize generic cost modelling methods to develop cost models for the main urban transit systems operated by CTA.

Four generic approaches for estimating cost models for transit services were thoroughly and comparatively reviewed. These approaches include causal factor method, cost allocation methods, regression method and temporal variation methods. Cost allocation methods were particularly applied in this research to estimate different cost allocation models for four of the main transit systems operated by CTA, namely buses, minibuses, river buses, and trams. In the process of building these models, a generic algorithm for estimation of cost allocation models was developed and presented.

For each of the transit systems, five cost allocation models of varying sophistication were developed using CTA actual budget expenses figures for 95/96 as well as CTA actual operating statistics for the financial year 95/96. The first and the simplest of these models is known as the *average cost allocation model*, whereby total costs are allocated to a single representative produced output such as travelled-km, operable hours or operable vehicles. The second, known as the *fully cost allocation model of input based cost categories*, looks at the list of budget inputs and allocates the cost of each input over a set of representative and generic produced outputs, usually taken as travelled-km, operable hours and operable vehicles. The third, which can be referred to as the *fully cost allocation model of activity based cost categories*, also looks at the list of budget inputs, classifies each input into what can be designated as activity based cost categories, namely operational, maintenance, general and administration cost categories. It then allocates each classified (activity based) cost item over the same set of representative produced outputs.

The fourth, which can be referred to as the *fully cost allocation model of temporal variation based cost categories*, looks at the list of budget inputs, classifies each input into what can be designated as temporal variation based cost categories, namely variable, semivariable and fixed cost categories. It then allocates each classified (temporal variation based) cost item over the same set of representative produced outputs. Finally the paper presents the fifth and most sophisticated cost allocation model, which is referred to as the *fully cost allocation model of activity based cost categories further disaggregated into temporal variation cost categories*. This looks at the costs classified in accordance with generic activity types and further subclassifies each item into another set of well defined cost categories based on their temporal variation, namely variable, semivariable and fixed cost categories. It then allocates each subclassified cost item over the same multiple set of representative outputs.

The development of the above cost allocation models is meant to assist in predicting and showing the relative magnitude of expected changes in the various cost categories, resulting from systems/services expansion or down-sizing for the transit modes operated by CTA. Thus, these models can be used as tools to assist in the evaluation of different strategies for improving transit service The development of such models is thought to contribute in raising the cost consciousness in CTA with an ultimate benefit of reducing costs and achieving efficiency gains.

The following conclusions were drawn from the developed models:

- It is obvious that cost sensitivity with respect to changes in operable vehicles is the highest, followed by cost sensitivity with respect to changes in operable hours and followed by cost sensitivity with respect to changes in travelled-km.
- Cost sensitivity is directly related to the size of the particular operating unit.
- In general, the models, for the four modes, show similar trends in that on average the percentage contribution of costs resulting from the production of:
  - travelled-km is ~14%;
  - operable hours is ~21%;
  - operable vehicles is ~64%.

This percentage ranking was expected as costs resulting from the production of operable vehicles would include such costs as depreciation and all staff related costs. These are significant cost items. However, these big differences between costs resulting from the production of operable vehicles versus the other two types of costs signifies such problems as high staff related costs resulting from overstaffing. In addition, it can be observed that costs resulting from the production of travelled-km are less than those costs resulting from the production of operable hours. This signifies the problem of high maintenance requirements resulting from the ageing of existing fleets and causing high maintenance costs related to operable hours.

- The models reveal the dominance of operating costs, where this type of costs constitutes ~49–55% of the total cost for the four CTA transit systems. In addition, it is obvious from the models that the operation costs resulting from the production of operable vehicles is significant. This can be attributed to depreciation costs as well as to overstaffing of operation staff.
- On the other hand, maintenance costs constitute ~20–27% of the total cost. Maintenance costs resulting from the production of operable vehicles is very minor, which seems to indicate that there is no problem of overstaffing of maintenance staff. However, the problem of ageing fleet causes an increase in maintenance requirements and, hence, maintenance costs related to operable hours.
- General and administration costs constitute ~21–31% of the total cost.
- The models reveal that variable costs constitute ~32–39% of the total cost for the four CTA transit systems. It is obvious from the models that variable costs result mainly from the production of operable hours and travelled-km.
- On the other hand, semivariable costs constitute only ~5–10% of the total cost.
- The models show the dominance of fixed costs, which constitute ~56–62% of the total cost. Fixed and semivariable costs result mainly from the production of operable vehicles.
- The models reveal that operation variable costs constitute ~10–17% of total costs. This is mainly sensitive to changes in travelled-km.
- On the other hand, maintenance variable costs constitute ~16–24% of total costs. This is mainly dependent on changes in operable hours.

- The models show the non-existence of general and administration variable costs.
- The models also reveal that operation semivariable costs constitute $\sim 3-6\%$ of total costs. This is mainly sensitive to changes in operable vehicles.
- On the other hand, maintenance semivariable costs constitute $\sim 0.5-3\%$ of total costs. This is mainly dependent on changes in operable hours.
- The models show the minor contribution of general and administration semivariable costs. This type of costs constitute only $\sim 0.2-0.4\%$ of total costs.
- The models reveal that operation fixed costs constitute the highest percentage share of total costs, i.e. $\sim 25-38\%$. This is mainly sensitive to changes in operable vehicles.
- This is followed by general and administration fixed costs, which constitute $\sim 21-30\%$ of total costs. This is also mainly dependent on changes in operable vehicles.
- On the other hand, maintenance fixed costs constitute a minor percentage share, only $\sim 0.7-1.3\%$ of total costs. This is also mainly dependent on changes in operable vehicles.
- The most dominant cost relations are:
  - *First*: operation fixed costs being sensitive to changes in operable vehicles
  - *Second*: general and administration fixed costs being sensitive to changes in operable vehicles
  - *Third*: maintenance variable costs being sensitive to changes in operable hours
  - *Fourth*: operation variable costs being mainly sensitive to changes in travelled-km.

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