SUSTAINABILITY ANALYSIS OF TRANSPORTATION INFRASTRUCTURE IN WATERLOO, ONTARIO

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Introduction

Transportation infrastructure is a major component of municipal budgets. A sample of financial statements from four Ontario municipalities of varying jurisdiction shows that transportation costs can account for 15-40% of a municipality's operating budget (Baker, Jackson, KPMG, 2016; Deloitte LLP, 2016; KPMG, 2016; St Amant, Rossini, Wallace, PricewaterhouseCoopers LLP, 2016). Municipalities employ key performance indicators to track the fiscal sustainability of their spending, but many of these indicators come with caveats that prevent direct comparisons. Infrastructure, population and the physical supply of infrastructure are often not included together in a single indicator, making it difficult to track trends where only one of these factors changes, and make insights into the fiscal sustainability of municipalities.

This research studies two facets of fiscal sustainability. First, an indicator is proposed that combines infrastructure supply, population, and expenditures, with the goal of enabling sustainability analyses that make use of one or more of these factors. Second, a sustainability analysis is performed for the road and transit networks in the City of Waterloo, Ontario, at the local and regional level. The proposed indicator is evaluated against a series of existing indicators covering 25 years of transit funding, and 11 years of road funding, ending in 2015. By covering over a decade of spending history, insights may be made into the long-term sustainability of transportation infrastructure in Waterloo.

Literature Review

The long-term ability of governments to earn and spend money on infrastructure has been explored in a series of previous academic literature and government documents. A selection of key performance indicators (KPI) related to these expenditures is provided in Table 1. Many of these indicators address either population or infrastructure supply, but often do not take account for one of the two.

Table 1: Existing infrastructure growth key performance indicators

KPI	Definition	Characteristics	Sample Usage
Debt-to-GDP ratio	Debt held as a percent of GDP	Ties debt to economic health of jurisdiction, ignores population and infrastructure supply	IMF (International Monetary Fund, 2016), literature (Hiraga, 2016)
RE/$1000 PI	Revenue and/or expenditures per $1000 of personal income	Ties revenue and spending levels to wealth of jurisdiction, ignores infrastructure supply	Literature (Dalehite, 2008)
RE per capita	Revenue and/or expenditures per person	Ties revenue and spending levels to population, ignores infrastructure supply	Literature (Dalehite, 2008)
OE per lane km	Operating expenditures per lane kilometre (roads)	Ties spending levels to infrastructure supply, ignores population	Ontario Financial Information Returns (Hettinga, Mennill, & Patel, 2016)
OE per trip	Operating expenditures per passenger trip (transit)	Ties spending levels to infrastructure demand, ignores infrastructure supply and population	Ontario Financial Information Returns (Hettinga et al., 2016)

In this study, an additional indicator is proposed. This indicator is a combination of two constituent indicators: total expenditures per capita (TEcap) and infrastructure supply per capita (IScap). Infrastructure supply is represented by lane kilometres for roadways, while revenue vehicle kilometres are used for transit. These values are indexed to a base year, and the rate of change in TE per capita is compared to the rate of change in infrastructure supply per capita, following the expression:

$$i = \frac{TEcap_{current} - TEcap_{index}}{TEcap_{index}} - \frac{IScap_{current} - IScap_{index}}{IScap_{index}} \quad (1)$$

Where,

i is the value of the proposed indicator;
current represents the study year; and
index represents the index year.

If *i* is negative, then compared to the index year, the relative increase in total expenditures per capita is less than the relative increase in infrastructure supply per capita, suggesting that the per unit cost of maintaining infrastructure at the given population levels is lower. Conversely, a positive *i* suggests the per unit cost is higher.

The goal of the proposed indicator is to capture changes that would not be identified by previous indicators. More specifically, the proposed indicator will reflect changes to any combination of infrastructure supply, total expenditures or population. For instance, a population boom that coincides with unchanged infrastructure supply and spending would theoretically mean the infrastructure is cheaper to maintain per unit in the sense that less money is spent per person. Similarly, dramatic increases in spending that outpace inflation, but result in the same level of infrastructure at relatively even population levels, would reflect higher costs per unit of infrastructure or per person. Neither of these changes would be captured by traditional indicators. And, as a result, insufficient information is available to determine the fiscal sustainability of an infrastructure system over time.

Methods

This analysis builds on the work done in a previous study (Terry, Casello, & Bachmann, 2017) by analyzing expenditures over a 25-year period for transit and an 11-year period for roads. Active transportation is included in the road analysis, since the operating costs for this mode in most years were part of the roads budget. In the previous study, the active transportation values reported were primarily limited to capital costs, hence it was possible to separate active transportation from roads. Like the previous study, this analysis focuses on per capita costs from the perspective of a resident in the City of Waterloo, Ontario.

The methods used for calculating government expenditures have progressed from the previous study, where operating and capital budgets for the City of Waterloo and Region of Waterloo were used to estimate the average revenue share of funding for transportation and water infrastructure from 2014 to 2016. In this prior study, the realized values of operating budgets were taken from the following year's budget (except for 2016 where the projected value was used). On the other hand, the capital budgets were taken from the current budget year's forecast, acknowledging that these estimates would likely overestimate the value of capital expenditures compared to the realized operating expenditures, since forecasts represent the upper spending limit for each project.

In this analysis, the primary sources of data used were the Financial Information Returns (FIRs) (Ontario Ministry of Municipal Affairs, 2016) for the City of Waterloo, the Region of Waterloo and the City of Kitchener. These documents are submitted annually to the Ontario Ministry of Municipal Affairs, using a standardized series of schedules that report on various aspects of a municipality's financial health. The standardization of the data format enables easier comparison between jurisdictions, since the differences in organizational structures between municipalities causes challenges in interpreting inclusions and exclusions from each municipality. Of importance to this study are the operating expenditures schedules (Schedule 40 from 2000-2015, Schedule 4 before 2000), which report on how much a municipality spends per program (e.g. roadways) in the operating budget. These data are more general than what is included in most budgets, but served the purpose of distinguishing between road expenditures and transit expenditures. Similarly, the capital expenditures data (Schedule 51C from 2010-2015, Schedule 52 from 2000-2008, Schedule 6 before 2000) reports expenditures by program in the capital budget.

In 2009, where Schedules 51C and 52 were not provided, and no clear alternative was given, the capital budgets for the City of Waterloo and Region of Waterloo were used. For the Region of Waterloo, unused capital amounts by program were reported in the 2010 capital budget (Holling, 2010), which were subtracted from the allocated capital amounts by program in the 2009 capital budget (Ryan, 2009) to estimate how much was spent in 2009. The City of Waterloo re-released the same 2008-2010 capital budget in 2008, 2009 and 2010, with updates each year to reflect how its multi-year budget had changed annually. Because of this, the 2009 update (Mavin & Eskens, 2009) was used to clarify the 2009 capital values.

Due to the change in ownership of the municipal transit system in 2000, the Region of Waterloo FIRs were used for the year 2000 and afterwards for transit data, and the City of Kitchener FIRs were used prior to 2000. Operation of transit services in the City of Waterloo was provided by Kitchener before shifting to the Region, so Kitchener's financial data were assumed to be the most accurate representation of transit expenditures before 2000. The Region's finances were used for regional roads, while the City of Waterloo's finances were used for local roads. Between the two jurisdictions, accurate estimates of expenditures in the City of Waterloo were developed.

After costs were calculated for roads and transit, other data were required to calculate the proposed and existing indicators. General CPI values were gathered from Statistics Canada (Statistics Canada, 2017a; 2017b) and all fiscal records were converted to 2016 dollars. Population values were gathered for the City of Waterloo, Kitchener and the Region of Waterloo for use in the per capita analyses. Population estimates

for the City of Waterloo were collected from the Region (V. Martin, personal communication, December 5, 2016); estimates for Kitchener were collected from the audited financial statements using the six-year financial review to account for revisions in population estimates. Finally, estimates for the Region of Waterloo were collected from the Region's website (Martin & Parkin, 2016). Trip data for the regional transit system was collected from regional FIRs for the years 2005-2015 for use in the per trip analyses.

To represent infrastructure supply in the sustainability analysis, road lengths were measured in lane kilometres and transit supply was measured as revenue vehicle kilometres. Road lengths in lane kilometres were collected from the City of Waterloo FIRs for the years 2005-2015 for city roads, and from the Region of Waterloo directly for the same period for regional roads. Revenue vehicle kilometres were collected from Grand River Transit (B. Allen, personal communication, February 24, 2017), which serves as the Region's transit agency.

Once all the supporting data were gathered, each indicator could be calculated for transit infrastructure and road infrastructure, then converted into indices, as shown in Table 2. For ease of comparison, each indicator is compared as a percent change to the 2005 value to provide an index, where an index of 0 represents the 2005 value. The indices are therefore intended to be read from 2005 toward 1991, and from 2005 toward 2015, where values below 0 represent increased per unit cost compared to 2005, and values above 0 represent decreased per unit cost compared to 2005. Indexing from 2005 instead of 1991 was done to provide an easier comparison of the road growth indicators, where the available infrastructure supply data only went back to 2005. The intent is that values that trend extremely positively over time would represent decreased fiscal sustainability, due to increasing costs per unit. Conversely, values that trend negatively over time would represent increased fiscal sustainability, to a degree, due to decreasing costs per unit. The ideal scenario would have values stay constant over time, which would indicate that a sustainable financing system has been developed.

Table 2: Infrastructure growth index calculation methods

Index	**Calculation method**	**System**
Proposed indicator (TE per capita vs. lane km per capita)	Percent change in (total expenditures / population) since 2005 minus percent change in (lane kilometres / population) since 2005	Roads
Proposed indicator (TE per capita vs. rev. veh. km per capita)	Percent change in (total expenditures / population) since 2005 minus percent change in (revenue vehicle kilometres since 2005 / population) since 2005	Transit
TE per capita	Percent change in (total expenditures / population) since 2005	Roads, transit
OE per lane km	Percent change in (operating expenditures / population) since 2005	Roads
TE per lane km	Percent change in (total expenditures / population) since 2005	Roads
TE per rev. veh. km	Percent change in (revenue vehicle kilometres / population) since 2005	Transit
TE per trip	Percent change in (total expenditures / passenger trip) since 2005	Transit

Results

A comparison of transit growth indicators is presented in Figure 1. The proposed indicator (circles) is compared against total expenditures (TE) per capita (squares), TE per trip (downward-pointing triangles), operating expenditures (OE) per trip (upward-pointing triangles) and TE per revenue vehicle kilometre (diamonds). TE and OE per trip were included to provide some comparison to the methods used in Ontario's FIRs, but are only shown from 2005-2015 due to the availability of ridership data. TE per revenue vehicle kilometre was included to represent a more accurate infrastructure supply indicator comparable to the use of lane kilometres in roads. In all indicators using TE, the highest indices are in 2014 and 2015, which is likely due to the construction of Waterloo's light rail transit system, with much lower values in prior years. The TE per capita indicator tends to suggest less sustainable funding compared to 2005 than the other indicators, while the TE per trip indicator tends to suggest more sustainable funding from 2005-2013. The proposed indicator and TE per revenue vehicle kilometre indicator suggest nearly equal results until 2012, when the proposed indicator begins to suggest a higher trend toward unsustainable funding than the TE per revenue vehicle kilometre indicator.

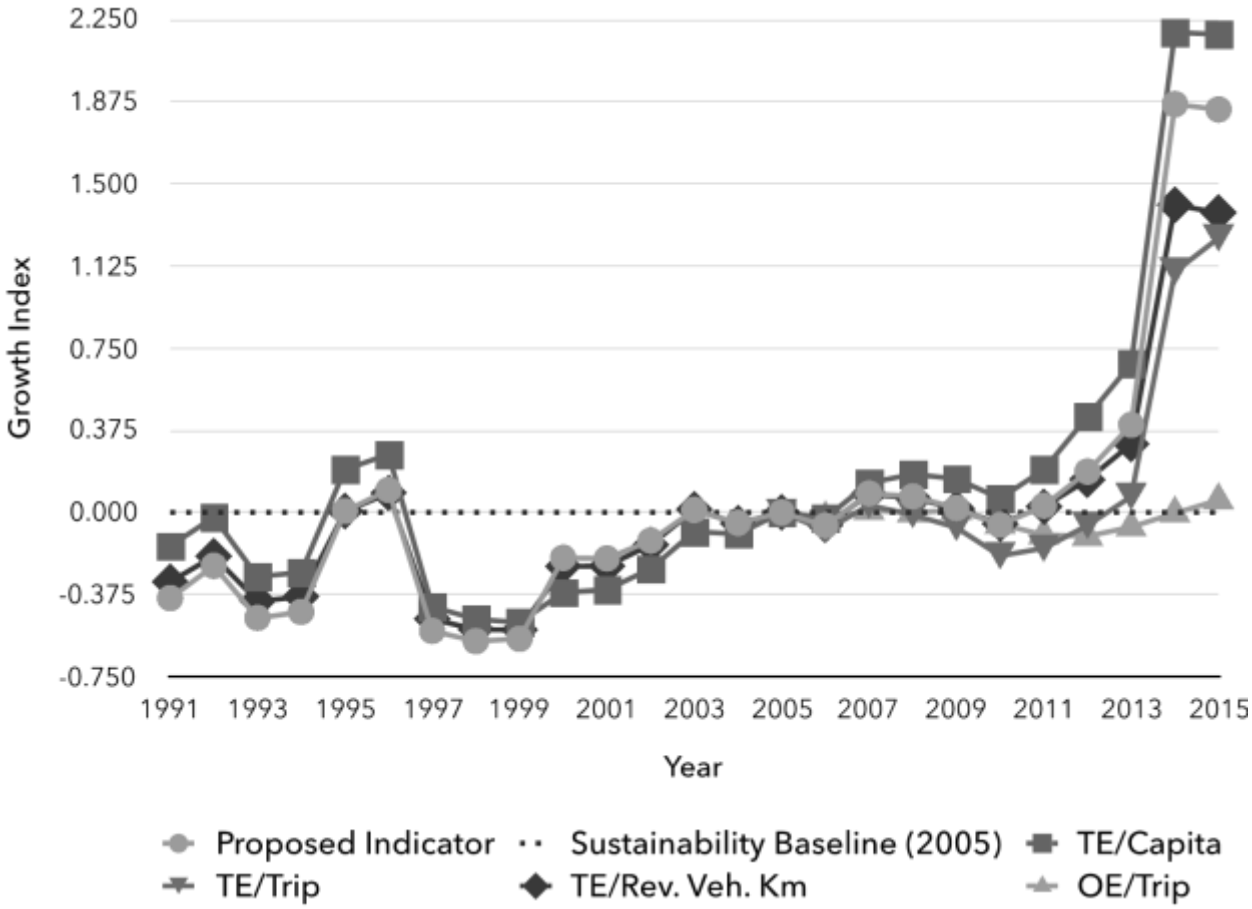

Figure 1: Transit growth indices from 1991-2015 (2016$, indexed to 2005).

A comparison of road growth indicators is presented in Figure 2. The proposed indicator (circles) is compared against TE per capita (squares), TE per lane kilometre (diamonds), and OE per lane kilometre (triangles). OE per lane kilometre is included to provide direct comparison to the reporting methods used for Ontario's FIRs up to 2014, since capital costs are often not included in the FIR's key performance indicators. The OE per lane kilometre values are adjusted for inflation and use the same cost calculation method as the other indicators instead of the actual values found in the FIRs to provide a better comparison. The proposed indicator is visually most like the TE per capita indicator, but every indicator makes different suggestions about the sustainability of road infrastructure in subsequent years compared to 2005, although they all suggest that sustainability has decreased since then to varying degrees. The TE per capita indicator suggests the closest return to 2005 per unit cost levels, the TE per lane kilometre indicator initially suggests a higher level of unsustainable spending between 2005 and 2008 before aligning with the other indicators, and the OE per lane kilometre indicator suggests a slow and stable trend toward unsustainability across the 11-year analysis. The proposed indicator tends to suggest a higher level of unsustainable spending between 2009 and 2015 compared to 2005 than the other TE indicators.

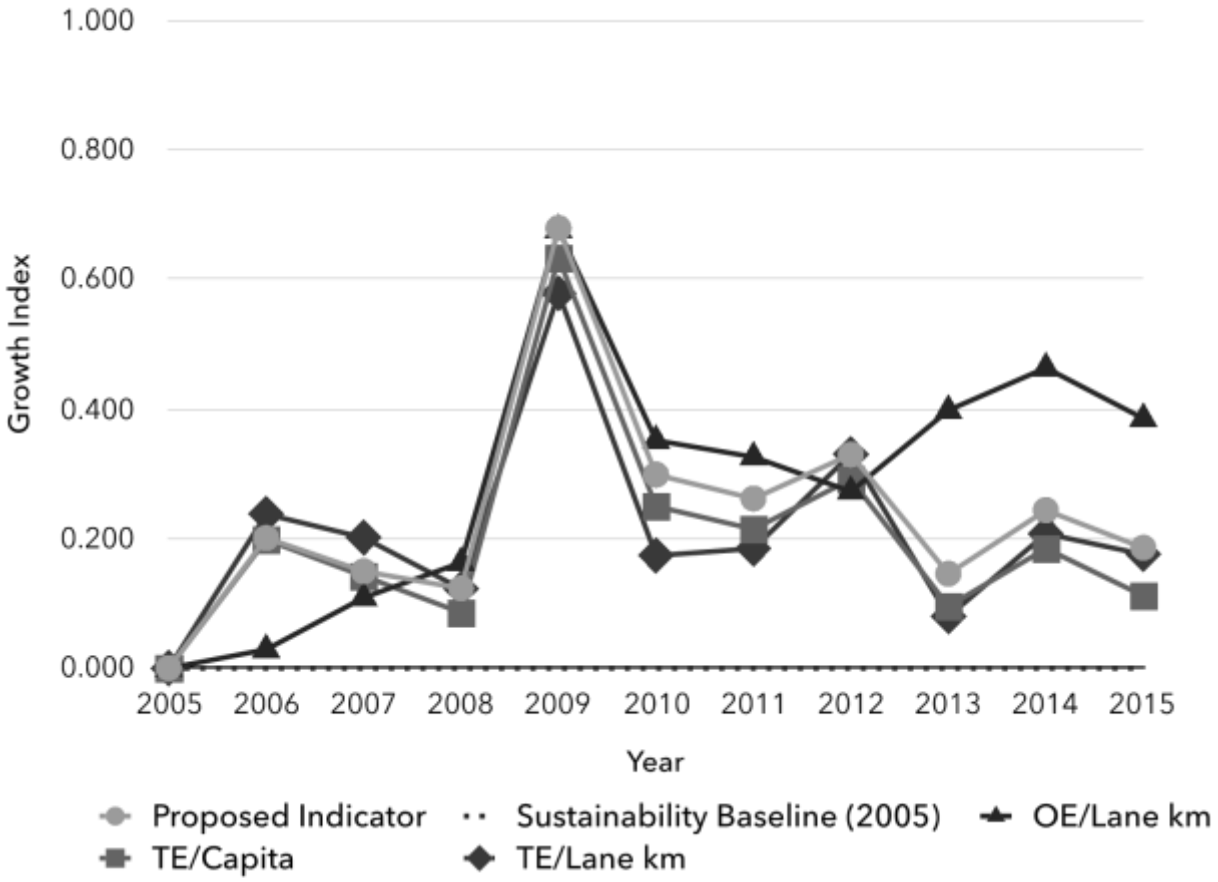

Figure 2: Road growth indices from 2005-2015 (2016$, indexed to 2005).

Discussion

Across all indicators that include capital costs, transit service was found to have a lower per unit cost than 2005 levels in the years 1991-1994, 1997-2004, 2006, and 2010. Additional years were also found to meet this criterion depending on the indicator used, but these transient years did not strongly correlate with a lower per unit cost. Over the long term, the fiscal sustainability of transit funding was turbulent in the years where Kitchener Transit served the City of Waterloo, but once it fell under the regional jurisdiction of Grand River Transit (GRT), the key performance indicators indicate a more stable and sustainable trend in the years 2003-2011. This continued until the beginnings of the construction of Waterloo's light rail transit system in 2011, where the trend pointed toward rapidly increasing unsustainability. The OE per trip analysis shows that, while there has been a slight increase in the per unit cost, the sustainability trend has been quite stable, likely a sign that the upward shock is just a side-effect of building the light rail transit system. If this is true, then the shock should be eliminated in the next couple years once the bulk of the construction is finished.

For road service, every indicator including those with or without capital costs showed that roads were on a general upward trend in per unit cost, suggesting potential problems for long term sustainability. This was particularly true when only looking at the OE per lane kilometre indicator, which showed a stronger correlation of unsustainability. Of the included years, 2005 had the lowest per unit cost, so all growth indices were higher than 0. Interestingly, 2009 had a massive spike across all indicators. While this was the year where capital budgets were used instead of the FIRs for estimating the value of the capital expenditures at the local and regional levels, the capital and operating values did not seem individually at a much higher magnitude than those in the years prior or after.

Regarding the proposed indicator, there appears to be some utility when the analysis period covers a longer term, or when the spikes in costs per unit are much higher. This was noticeable in the more recent years in the transit analysis, and to a lesser degree, in the road analysis. However, all indicators in this analysis that used TE tended to give a similar result, suggesting that either the cost on its own is more of a contributing factor to the variances over time in the indices, or that the population and infrastructure supply and demand factors correlate well enough in practice that indicators making use of only one of the factors work most of the time.

Limitations and Future Work

A limitation in this analysis that could also be part of a future phase of this study is to identify transit revenues and expenditures that take place only in the GRT's urban service area. This would narrow down the scope of what City of Waterloo residents pay for, but may be challenging as the capital budgets for the GRT often mix urban and rural expenditures.

The use of the general CPI to represent inflation, while often used in governments as a baseline for wage increases or other regular annual increases, may not accurately reflect the increased price of goods and services that make up a transit or road service. A component of this project in the future will be to determine whether other inflation indices should be used to represent the increases in cost instead. The use of 2005 as a baseline for the analysis was also not ideal, but was made necessary by a lack of lane kilometre data available for roads at the local and regional levels. In the future, there would ideally be enough road supply data to conduct an analysis of roads from 1991 as well, allowing for 1991 to be the baseline in both evaluations. This would make it simpler to compare both systems, and make it easier to understand visually if transportation infrastructure is funded sustainably.

There is the possibility that some capital costs have been counted twice in this analysis. Money that went into reserves or reserve funds may have been included in operating costs, depending on the reporting

structure of each municipality's FIR, which would then be included again in the capital costs when the money is withdrawn from the reserve or reserve funds for capital expenditures. This enforces the desire to explicitly incorporate reserves and reserve funds into the analysis, to conduct a more transparent sustainability analysis of the city's infrastructure over time.

The analysis performed in this study is the first phase of a larger sustainability analysis of the City of Waterloo's infrastructure. There are two immediate goals for the second phase: analyzing reserves and reserve funds, and analyzing revenue sources. By analyzing the cash flows in and out of reserves and reserve funds, the intent is to conduct an "age of money" analysis, where it could be determined over time how long a 1991 taxpayer's dollar lasts versus a 2015 taxpayer's dollar. This could lead to a better understanding of which revenue sources go into these reserves. Following up on the previous study that analyzed sources of intergovernmental transfers and reserves (Terry et al., 2017), transfers from the provincial and federal governments could also be broken down into their origin revenue sources, such as sales tax or income tax, enabling a determination of how the composition of these origin revenue sources has changed over time. Incorporating other municipal revenues could also enable long-term tracking of whether municipalities are relying more on higher levels of government to fund their transportation infrastructure. Once property taxes are included in the revenue analysis, there is sufficient regional data to separate the origin of regional property taxes by lower-tier municipality, such as the City of Waterloo or Kitchener. These will lead to a better understanding of a larger question, which is whether or not current residents pay for infrastructure intended for new residents versus their own needs.

Conclusion

Discussions around environmental and fiscal sustainability tend to focus on costs, population and availability of resources. This study developed and implemented an indicator that incorporates all three criteria, to minimize events where a change in one of these factors is not reflected in the available key performance indicators. Using the City of Waterloo as a sample city, an analysis was done of local and regional transportation infrastructure, where this new indicator was included as a way of verifying its accuracy and determining if it brought new insights into the fiscal sustainability of the study area. In practice, it gave similar results to the existing indicators, suggesting that it may be of similar quality, or that in this example there were not enough drastic changes in the relevant criteria to notice any major differences.

The transit and road infrastructure analysis showed that transit, on a whole, has been relatively sustainably funded since it was managed by Grand River Transit. Roads have also been somewhat sustainably funded, although they tend to show a stronger upward trend in per unit cost, which could indicate a slight trend toward increasing unsustainability. By conducting similar analyses on other jurisdictions, and by including more components of revenue sources in the analysis, this study could be made more definitive.

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