Regulatory Structures and their Impact on the Sustainability Performance of Public Transport in World Cities

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Keywords
Sustainability; Regulation; Performance; Environment; Social; Economic; Public Transport; World Cities

Classification codes (minimum of 3, maximum 6):
H4 Publicly Provided Goods
L9 Industry Studies: Transportation and Utilities
R4 Transportation Systems

ABSTRACT

This paper describes a new measure of the sustainability performance of public transport in 88 world cities adopting 15 indicators including Environmental, Social, Economic and System Effectiveness sustainability. Sustainability performance is then explored for cities with only "Public" operations or others with some degree of commercial operation ("Non-Public")

Results show no significant difference in aggregate total sustainability indicator scores between world cities with "Public"/"Non-Public" operations. However Social Sustainability indicators are significantly different with "Public" operations having better Social Sustainability performance than "Non-Public".

For individual component indicators, three of the four Social Sustainability component indicators have average normalised scores suggesting statistically significant differences between "Public" and "Non-Public" city scores with "Public" cities performing better than "Non-Public". The indicators and their relative advantage to "Public" cities being Trip distance (24%), Affordability (34%) and PT related deaths (29%). However results also show that operating costs per passenger km and cost recovery are higher in "Non-Public" cities suggesting higher elements of Economic Sustainability in "Non-Public" based Public Transport cities

The paper concludes with a summary and discussion of the results including implications for regulatory practices and areas for future research.

[186 word Max=200]

1. Introduction

Cities play a leading global economic, social and environmental role in human existence on planet Earth. From 2007, for the first time in history, more than half of the world's population lives in cities (United Nations Population Fund 2007). Between 2000-2030, the world's urban population is expected to double. The 21st century is said to be the 'Urban Millennium' where the functioning of cities has a principal influence on the future of human kind (United Nations Population Fund 2007).

Transport is a major economic, social and environmental challenge to the functioning of world cities. Travel in developed cities is dominated by the private car (Cosgrove et al. 2009) which has generated the global problem of urban traffic congestion (Cervero 1991, Arnott and Small 1994) imposing significant and growing environmental and economic costs on world cities. In Australian major cities congestion is estimated to cost $Aust 9.4 B p.a. (2005) and is expected to rise to $Aust 20.4 B by 2020 (Bureau of Transport and Regional Economics 2007). Urban liveability is at risk as a result of environmental damage caused by the private car (Vuchic 1999) while the segregation of urban communities by growing 'traffic sewers' imposes social costs on disadvantaged communities (Rosenbloom 2007). Transport, mainly private car travel, is the only sector of the UK economy for which environmental emissions in 2007 are higher than in 1990 (Woodcock et al. 2007).

Improving existing and developing new urban public transport (PT) systems has been widely seen as part of a global solution to the economic, social and environmental challenges faced by world cities (Vuchic 1981, Beimborn et al. 1993, Larwin 1999, Bunting 2004). Indeed it is a commonly held view amongst the planning and transport community that public transport systems are 'sustainable' because they address economic, social and environmental transport impacts in an effective way. However the assumption that public transport systems are, by their nature, 'sustainable' is rarely tested (De Gruyter et al. 2017) and deserves scrutiny.

Regulatory reform of urban public transport has also been a major world trend, due to concerns about the economic performance (and economic sustainability) of public transport. Escalating government public transport subsidies have driven many governments to explore private operation or involvement in the management of urban transit systems (Currie 2016). Major drivers have been to encourage greater market competition and reduce costs. The rationale for encouraging competition in public transport is that public ownership is often thought to create higher cost and less customer focused operations (Currie 2016).

While much research now demonstrates cost savings and arguably improved 'economic' sustainability as a result of private sector involvement in publicly owned public transport services, no research has explored how this has affected its social and environmental sustainability performance.

This research paper is an empirical exploration of public transport sustainability from an environmental, social, economic, and system effectiveness perspective. It aims to explore these dimensions of sustainability for public transport in major world cities which have public sector vs commercial or private sector involvement in public transport. It aims to answer the question; does public sector or more market based involvement act to affect the sustainability performance of public transport in cities (and if so how)?

The paper adopts a new methodology previously developed by the authors (De Gruyter et al. 2017) to empirically measure the sustainability of public transport in world cities from an economic, social, environmental and system effectiveness perspective. The method adopts data on public transport systems in over 100 cities produced by the International Association for Public Transport (UITP 2001, UITP 2015). The original application of the sustainability methodology was to explore patterns of sustainability performance between cities in world regions (De Gruyter et al. 2017). The approach has also been adopted to explore empirical links between land use patterns and their influence on the sustainability of public transport in world cities (Currie and De Gruyter 2017). This paper seeks to adopt this approach to explore how and if public vs private/market influence on public transport in world cities acts to influence sustainability performance.

The paper is structured as follows; the next section presents a description of the method used to measure sustainability performance. This is followed by an outline of the approach used to apply the method to assess public transport in cities with only public vs private/market influenced operations. Results are then described. The paper concludes with a summary of key findings and discussion of their implications for practice and an outline of areas for future research.

2. Methodology

2.1 Measuring Sustainability Performance

The methodology developed by the authors (De Gruyter et al. 2017) adapts 'Miller's framework' (Miller 2014) to assess and compare the sustainability performance of urban public transport systems in world cities. This framework includes measures of economic, social, environmental and system effectiveness sustainability. The adaptation is shown in Table 1 and contains a total of 15 indicators, grouped into the same four headings used by Miller (2014) to reflect key dimensions of public transport sustainability. Indicators for each city use data collated by the International Association for Public Transport (UITP 2001, UITP 2015). In practice, high quality data measuring a wide range of aspects of sustainability performance is not available. To some extent the method takes a pragmatic approach by fitting sustainability measures around available data.

Indicators are 'normalised' to give a value between 0 and 1 to allow comparison between cities on a comparable basis. Indicators have equal weight in the assessment process because there is no evidence to suggest some aspects of sustainability are more important than others (Haghshenas and Vaziri 2012, Miller et al. 2016).

As Table 1 shows some indicators have 'better' or more desirable results if their outcome values are lower while other have better values that are higher. To aid better understanding of the final aggregate indicators all values are adjusted such that outcome sustainability values are better if they are higher.

Data was collated using this approach for over 100 cities. In addition average performance indicators were computed for world regions of cities including Europe, North America, South America, Asia, Africa, the Middle East and Oceania.

Table 1: Indicators for assessing urban public transport sustainability

ID	Indicator	Units	Desirability
A	**ENVIRONMENTAL**		
A1	Quantity of energy consumed	MJ/pkm	Less is desirable
A3	Mass of total pollutants emitted (e.g. NO_x, VOC, CO_2)	kg/ha	Less is desirable
A5	Land area consumed by public transport facilities	% of urban area	Less is desirable
B	**SOCIAL**		
B1	System accessibility	pkm/capita	More is desirable
B4	Average user trip distance	km	Less is desirable
B5	Affordability	10^{-4} per capita GDP/trip	Less is desirable
B9	Public transport related deaths	fatalities/billion-pkm	Less is desirable
C	**ECONOMIC**		
C1	Annual operating cost	$US/pkm	Less is desirable
C4	Cost recovery (proportion of costs recovered)	% of total costs	More is desirable
C6	Passenger km travelled per unit GDP	pkm/$US	More is desirable
C8	Average time per trip	mins	Less is desirable
D	**SYSTEM EFFECTIVENESS**		
D1	Average occupancy rate of passenger vehicles	% of seated capacity	More is desirable
D3	Annual public transport trips per capita	trips/capita	More is desirable
D4	Public transport mode split	% of all trips	More is desirable
D5	Public transport fleet size	vehicles/million people	More is desirable

Source: De Gruyter et al. (2017)

2.2 Classifying City Public Transport into Public vs Private/Commercial

Data about public transport regulatory structures were gathered by a review of public transport sources in each city. Sources included websites of public transport agencies and operators as well as relevant literature e.g. (TTF 2012, Fiorio et al. 2013, Paget-Seekins et al. 2015). A city's public transport regulatory structure was classified as 'Public' if **all** operators are publicly-owned and as 'Non-Public' otherwise. This means that cities with only a small degree of private sector involvement were classified as non-Public. Of the more than 100 cities included in the UITP databases, it was possible to classify 88 cities in this way across Western Europe, Eastern Europe, North America, Latin America, Middle East, Africa, Asia, and Oceania. Overall only 25 cities were found to have 'Public' i.e. entirely public operated transport systems.

2.3 Data analysis

Relationships between public transport sustainability indicators and regulatory structures were investigated by comparing indicator scores between cities with Public structure and Non-Public structure. Individual indicators, composite indicators by each dimension of public transport sustainability (economic, social, environmental and system effectiveness), and an overall composite indicator (total public transport sustainability), were considered. A t-test was also conducted to check if a relationship is statistically significant. In addition, correlations between sustainability indicators and regulatory structures based on world regions were also examined using the Pearson correlation coefficient.

3. Results

3.1 World City Classification

Table 2 shows the classification of world cities into 'Public' and 'Non-Public' categories.

Table 2 : Regulatory structures by cities

City	Classification	City	Classification	City	Classification
Western Europe		**Eastern Europe**		Tehran	Non-Public
Graz	Public	Prague	Non-Public	Riyadh	Non-Public
Vienna	Non-Public	Budapest	Public	Abu Dhabi	Public
Brussels	Public	Cracow	Public	Dubai	Public
Copenhagen	Non-Public	Moscow	Non-Public	**Africa**	
Helsinki	Non-Public	**North America**		Cairo	Non-Public
Lyon	Non-Public	Calgary	Public	Abidjan	Non-Public
Marseille	Public	Montreal	Non-Public	Casablanca	Non-Public
Nantes	Public	Ottawa	Public	Dakar	Non-Public
Paris	Non-Public	Toronto	Public	Cape Town	Non-Public
Berlin	Public	Vancouver	Public	Johannesburg	Non-Public
Frankfurt	Non-Public	Atlanta	Public	Tunis	Non-Public
Hamburg	Public	Chicago	Public	Harare	Non-Public
Dusseldorf	Non-Public	Denver	Non-Public	**Asia**	
Munich	Non-Public	Los Angeles	Non-Public	Beijing	Non-Public
Stuttgart	Public	New York	Non-Public	Hong Kong	Non-Public
Athens	Public	Phoenix	Non-Public	Delhi	Non-Public
Milan	Public	San Diego	Non-Public	Mumbai	Public
Bologna	Public	San Francisco	Public	Tokyo	Non-Public
Rome	Public	Washington	Non-Public	Kuala Lumpur	Non-Public
Amsterdam	Non-Public	**Latin America**		Manila	Non-Public
Oslo	Non-Public	Curitiba	Non-Public	Singapore	Non-Public
Barcelona	Non-Public	Rio de Janeiro	Non-Public	Seoul	Non-Public
Madrid	Non-Public	Salvador	Non-Public	Taipei	Non-Public
Stockholm	Non-Public	Sao Paulo	Non-Public	Bangkok	Non-Public
Berne	Public	Santiago	Non-Public	Ho Chi Minh City	Non-Public
Geneva	Public	Bogota	Non-Public	**Oceania**	
Zurich	Non-Public	Mexico City	Non-Public	Brisbane	Non-Public
Glasgow	Non-Public	**Middle East**		Melbourne	Non-Public
London	Non-Public	Jerusalem	Non-Public	Perth	Non-Public
Manchester	Non-Public	Tel Aviv	Non-Public	Sydney	Non-Public
Newcastle	Non-Public	Mashhad	Non-Public	Wellington	Non-Public

By region a mix of 'Public'/'Non-Public' operations were found in Western and Eastern Europe and North America. Oceania, Latin America and Africa have entirely 'Non-Public' operations while Asia and the Middle East have mainly 'Non-Public with a few 'Public' operations. Overall only 25 of the 88 cities studied had entirely 'Public' operations.

3.2 Average City Sustainability Scores

Table 3 shows the average city sustainability scores for "Public" and "Non-Public" operations. These are illustrated in Figure 1.

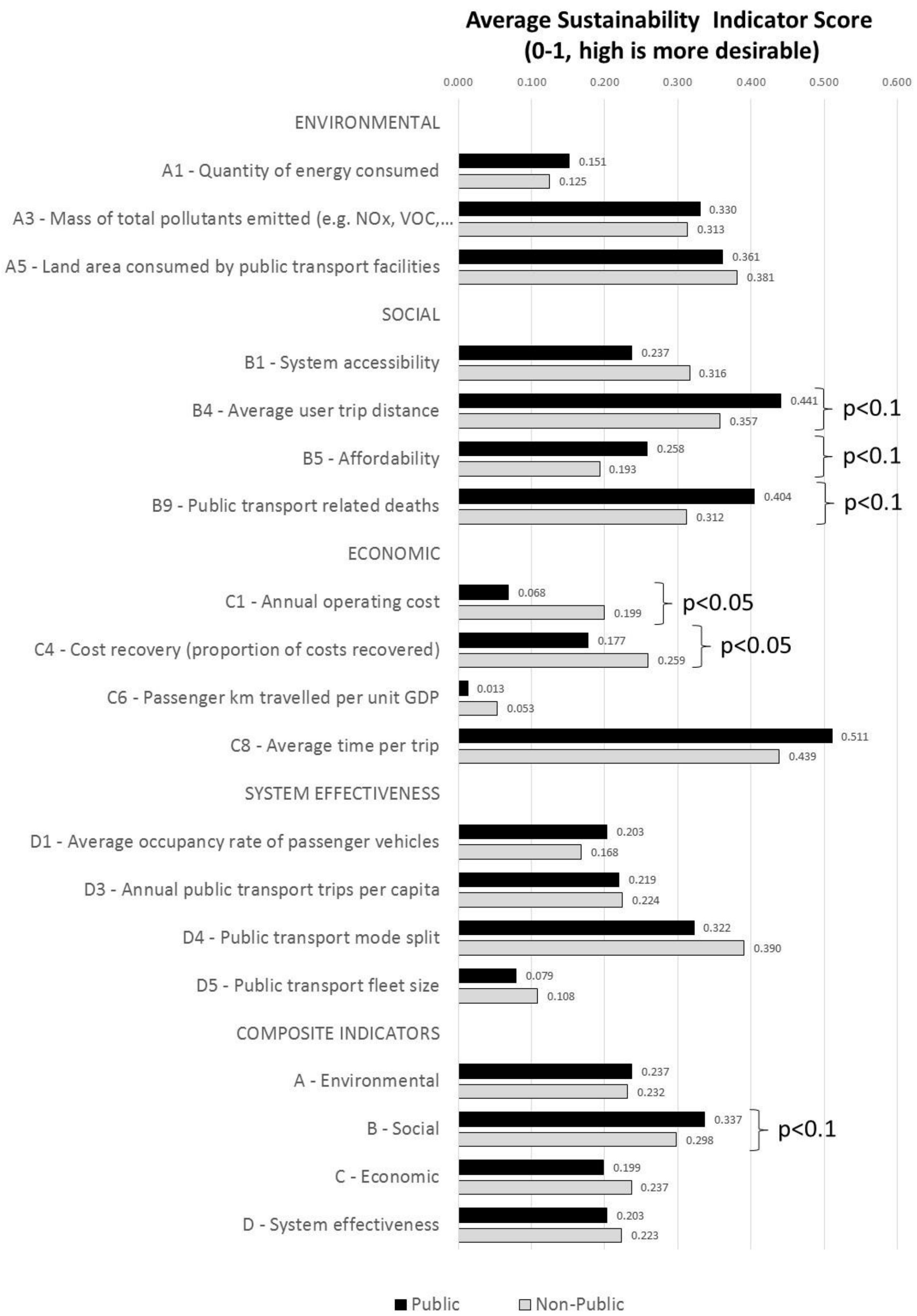

Figure 1 : Average city sustainability indicator scores by "Public"/"Non-Public" Operation

Table 3 : Average city sustainability indicator scores by "Public"/"Non-Public" Operation

ID	Indicators	Regulatory structure		n	T-test
		Non-Public	Public		
	ENVIRONMENTAL				
A1	Quantity of energy consumed	0.125	0.151	82	
A3	Mass of total pollutants emitted (e.g. NO_x, VOC, CO_2)	0.313	0.330	80	
A5	Land area consumed by public transport facilities	0.381	0.361	18	
	SOCIAL				
B1	System accessibility	0.316	0.237	85	
B4	Average user trip distance	0.357	0.441	86	p<0.1
B5	Affordability	0.193	0.258	78	p<0.1
B9	Public transport related deaths	0.312	0.404	81	p<0.1
	ECONOMIC				
C1	Annual operating cost	0.199	0.068	77	p<0.05
C4	Cost recovery (proportion of costs recovered)	0.259	0.177	78	p<0.05
C6	Passenger km travelled per unit GDP	0.053	0.013	85	
C8	Average time per trip	0.439	0.511	85	
	SYSTEM EFFECTIVENESS				
D1	Average occupancy rate of passenger vehicles	0.168	0.203	83	
D3	Annual public transport trips per capita	0.224	0.219	87	
D4	Public transport mode split	0.390	0.322	87	
D5	Public transport fleet size	0.108	0.079	86	
	COMPOSITE INDICATORS				
A	Environmental	0.232	0.237	79	
B	Social	0.298	0.337	84	p<0.1
C	Economic	0.237	0.199	83	
D	System effectiveness	0.223	0.203	87	
	Total public transport sustainability	0.251	0.245	87	

Note: all indicator scores are normalised to give a value between 0 and 1; a higher score is more desirable across all indicator types.

Figure 1 and Table 3 results indicate that for the composite indicators:

- The total average composite sustainability score for "Public" operations is slightly lower (0.245) than "Non-Public" (0.251). However this finding is not statistically significant
- Composite average environmental indicators were slightly higher for "Public" (0.237) than "Non-Public" (0.232) but again this was not statistically significant.
- There is a statistically significant difference in composite social sustainability indicator scores with "Public" (0.337) having a much higher social sustainability score than "Non-Public" (0.298). The difference in composite Social Sustainability indicator scores suggests that on average "Public" operations had a score which was 13% more desirable than the average "Non-Public" city.
- Composite average Economic and System Effectiveness indicators were both lower for "Public" operation (0.199/0.203) than for "Non-Public" (0.237/0.223). However again none of these differences were statistically significant.

For the individual component indicators average city results were significant for only 5 sets of results. The results with the 90% level of statistical significance were all social sustainability indicators and included:

- B4 – Average User Trip Distance. Lower values of average trip distances are generally considered to be more sustainable. Cities with "Public" operations had a significantly better average trip distance score than "Non-Public" cities. This was statistically significant at the 90% level. The difference in indicator scores suggests that on average "Public" operations had an Average User Trip Distance normalised score which was 24% more desirable than the average “Non-Public” city.

- B5 – Affordability. This is measured as the cost of fares as a ratio of GDP per capita per trip. Cities with “Public” operations had a significantly better average trip affordability score (cheaper user price per trip) than “Non-Public” cities. This was statistically significant at the 90% level. The difference in indicator scores suggests that on average “Public” operations had an Affordability normalised score which was 34% more desirable than the average “Non-Public” city.
- B9 - Public transport related deaths. This is measured as fatalities/billion-pkm. Cities with “Public” operations had a significantly better PT related deaths score than “Non-Public” cities. This was statistically significant at the 90% level. The difference in indicator scores suggests that on average “Public” operations had a PT related deaths normalised score which was 29% more desirable than the average “Non-Public” city.

However not all statistically significant sustainability scores were in favour of “Public” operations. Two selected Economic sustainability measures favoured “Non-Public” rather than “Public” operations however both were at the higher level of statistical significance (95%) and included:

- C1 – Annual Operating Cost. This is measured as cost in $US/pkm. Cities with “Non-Public” operations had a significantly better Cost/Pkm than “Public” cities. This was statistically significant at the 95% level. The relative difference in indicator scores suggests that on average “Non-Public” operations had a cost/pkm normalised score which was 192% more desirable than the average “Public” city. A very big difference in average normalised scores.
- C4 – Cost Recovery. This is measured as the percentage of costs covered by farebox revenue. Cities with “Non-Public” operations had a significantly better cost recovery than “Public” cities. This was statistically significant at the 95% level. The relative difference in indicator scores suggests that on average “Non-Public” operations had a cost recovery normalised score which was 146% more desirable than the average “Public” city score. A very big difference in average normalised scores.

3.3 Average World Region of Cities Analysis

Figure 2 shows the results of an analysis by world region of cities where the percentage of cities with public only operations (“Public”) is shown by their average normalised sustainability score for the 4 categories of Environmental, Social, Economic and System Effectiveness. This indicates that:

- Of the 4 categories of sustainability Indicator explored, only the Social Sustainability composite indicator has an association between share of cities with “Public” operation and social sustainability. This has an R^2 correlation of 0.598 which is a very good correlation. The association is positive; world regions with higher shares of “Public” operation have higher Social Sustainability performance. This is led by Eastern Europe, North America and Western Europe. Africa, Latin America and Oceania have zero shares of cities with “Public” operation and very low Social Sustainability scores.

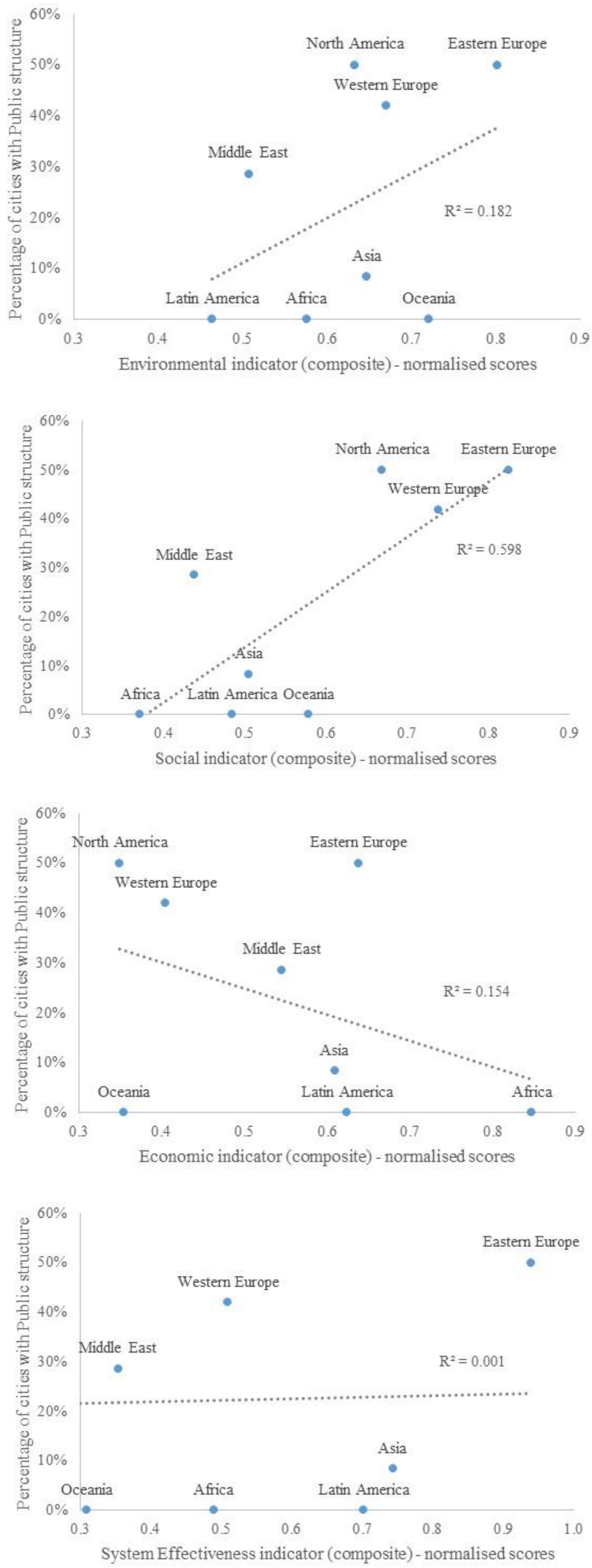

Figure 2 : Share of Average World City Region Cities in "Public" Operation and Regional Average Normalised Score by Sustainability Category

- Of the other 3 categories of Sustainability, Environmental indicators have the next most significant correlation between share of city regions with “Public” operation and Environmental sustainability; the R^2 correlation is 0.182 which is not a very good correlation. This weak correlation trends to a positive association with a higher share of “public” operation acting to have higher Environmental Sustainability performance.
- The Economic Sustainability measures by region have a very weak correlation between share of “Public” operations and Economic Sustainability; R^2 is 0.154. The trend is negative suggesting a higher share of “Public” operation acts to reduce Economic Sustainability.
- There is no correlation between System Effectiveness measures of Sustainability and the share of “Public” operations in cities in world regions.

4. Conclusions

4.1 Summary of Findings

Overall the world city sustainability analysis results suggest that there is no significant difference in aggregate total sustainability indicator scores between world cities with “Public” or “Non-Public” operations. However there is a significant difference in Social Sustainability indicators with “Public” operations having a much better Social Sustainability performance than “Non-Public” The relative difference suggests “public” cities’ performance score is on average about 13% better than “Non-Public” cities in Social Sustainability terms.

For individual component indicators, three of the four Social Sustainability component indicators have average normalised scores suggesting highly statistically significant differences between “Public” and “Non-Public” city scores with “Public” cities performing better than “Non-Public”. The indicators and their relative advantage to “Public” cities being Trip distance (24%), Affordability (34%) and PT related deaths (29%).

Not all individual indicators that were statistically significant had values that favoured “Public” over “Non-Public” cities. Two of the four Economic Sustainability indicators favoured “Non-Public” cities. The indicators were Annual Operating Cost/Pkm and Cost Recovery. Average normalised scores were considerably better for “Non-Public” cities with the relative score differences being 192% higher for Operating Cost/Pkm and 146% higher for Cost Recovery than “Public” scores.

The World Region analysis showed a strong positive correlation between the share of cities with “Public” operations and Social Sustainability scores with Eastern Europe, Western Europe and North America having the highest Social Sustainability scores. Other correlations were weaker with Environmental Sustainability indicators having a positive association with share of cities in “Public” operation and Economic Sustainability indicators having a negative association. No correlation was found for System Effectiveness indicators by World Region.

4.2 Discussion

The world growth of cities has made the 21st century the ‘urban millennium’ where the future success of the human race is tied to the success of cities where the majority now live.

Transport in cities presents considerable environmental, social and economic challenges and enhancing existing and expanding new public transport systems has been widely seen as a solution to these challenges. The environmental, social and economic performance of public transport is therefore important to the future of cities however this is not often measured.

This paper has presented a range of measures of sustainability performance of public transport. A key finding in relation to the above discussion is that, despite a common view that public transport is always sustainable, in practice there is a wide range of variability in the sustainability performance of public transport between cities; it does at all follow that all city public transport have high performance with regard to sustainability. In practice some are high in some aspects of sustainability while others do better in other categories. The authors' original research with regard to these measures found that by world region:

> *"In general the results suggest that western developed regions (Western Europe, North America and Oceania) have better performance on environmental and social indicators but poorer performance on system effectiveness and economic indicators. Asia and Latin America perform the other way round; better on economic and system effectiveness and worse on social and environmental indicators. Eastern Europe is one of the few with higher level performance all round."*
>
> (De Gruyter et al. 2017, p11)

A clear way forward for public transport to assist in addressing the challenges world cities face is for an all-round improvement to be made in relation to each category of sustainability. So western developed regions would target improvement in economic and system effectiveness sustainability measures while Asia and Latin America might target improvements in social and environmental sustainability.

The focus of this paper has been on links between public operations vs commercial or market orientation of operations in public transport and how this relates to the sustainability performance of public transport in world cities. In simple terms the results imply that "Public" only operations have better Social Sustainability performance (notably shorter travel distances, cheaper fares and better safety) than "Non-Public" operations but that "Non-Public" operations have elements of better performance with Economic Sustainability (operating costs per unit of travel and better cost recovery from fares). It is entirely feasible therefore that cities in some world regions can use commercialisation as a means to address economic sustainability problems in cities. If western developed regions of the world need better economic sustainability performance then commercialisation can assist with this regard. However the results imply this can harm their social sustainability performance.

An obvious solution to this dilemma would be to design public transport regulatory reform associated with commercialisation in such a manner that it protects and enhances social and environmental sustainability performance. The findings of this research imply that this requirement is missing in existing reforms; it could be argued that pre-existing regulatory reforms are more closely associated with cutting costs than in protecting the environment or in furthering progressive social policy. There is also an ideological perspective which might argue that social and economic sustainability objectives are, by their very nature, opposing choices in an ideological spectrum.

Perhaps the most significant implication of this research is that regulatory reform might be associated with undesirable sustainability outcomes and that these are critical aspects of the future viability of world cities. There are glimmers of good economic sustainability impacts of reform in the findings but these are not as clear as the negative aspects. We might argue therefore that there are significant future urban sustainability reasons to question the rationale for regulatory reform of public transport.

The research might also suggest a new way to conceptualise regulatory reform; if positive economic sustainability outcomes can result from reform then why can't it also protect and enhance environmental and social sustainability. Research should take this concept and apply it to reform models to seek out ways that all sustainability objectives can be better achieved in reform.

There is also much scope to improve the metrics assembled in the sustainability measures adopted in this research. A starting point for this is better data on world cities. The authors agree the data adopted is far from perfect however the sources used (from UITP) are the best yet assembled but more should be done to improve our knowledge of the performance of world cities in this regard.

Overall this paper has demonstrated that public sector operation of public transport in world cities seems to protect their social sustainability performance and that commercialisation can act to put this performance at risk. While commercialisation can improve economic sustainability there is a need to adjust reform ideology to also enhance environmental and social sustainability performance to ensure the effective development of world cities into the future.

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