ASSESSING SUSTAINABILITY AND ENERGY EFFICIENCY IMPROVEMENT MEASURES IN FREIGHT TRANSPORTATION

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ABSTRACT

Measures to improve energy efficiency and sustainability in freight transportation are well documented internationally. These range from improving vehicle aerodynamics to freight demand management; from driver training to alternative propulsion systems. South Africa is spatially challenged, with production often far away from ports and export markets. The freight system relies on old technology, prefers road-based transportation and has virtually no inter-modal facilities and no inland waterways to utilise. Adopting internationally successful measures might not be as rewarding in South Africa. The applicability of said measures needs to be investigated for South Africa. It needs to be determined what the viability of implementing measures is, what unique constraints there are and whether the skills and resources required for implementation are available. The paper starts with an overview of the obstacles facing freight transportation. An assessment of the potential success of implementing various measures follows. Measures are grouped into the following categories: non-viable, doubtful, neutral, potentially successful and extremely promising within a South African context. The ultimate objective is to indicate the most viable solutions for mitigating the energy demand and improving the sustainability of freight transport in South Africa.

INTRODUCTION

Hesse and Rodrigue (2004) indicate that "[…] freight transport is likely to consume an increasing amount of energy and land, and it contributes to a wide range of problems, such as air and noise emissions, congestion, traffic fatalities, etc." The need for continued economic growth necessitates growth in freight transportation. Due to the externalities associated with freight transport, however, this development must be managed responsibly. For this reason measures to improve energy efficiency and sustainability in freight transportation have been developed internationally. In the 2008 budget speech, Trevor Manuel, the Minister of Finance, alluded to the importance of implementing such measures, by saying that: "We have an opportunity over the decade ahead to shift the structure of our economy towards greater energy efficiency, and more responsible use of our natural resources and relevant resource-based knowledge and expertise. Our economic growth over the next decade and beyond cannot be built on the same principles and technologies, the same energy systems and the same transport modes that we are familiar with today." (Manuel, 2008)

Because adopting internationally successful measures might not be as rewarding in South Africa, it is imperative to determine which measures are the most suitable in the South African context. This will facilitate prudent investment and development decisions.

OBSTACLES FACING SOUTH AFRICAN FREIGHT TRANSPORTATION

There are many obstacles facing freight transportation in South Africa, some of which are unique to the country and some shared by other developing nations. These obstacles pose a threat to the successful implementation of energy efficiency and sustainability improvement measures that have achieved success in other (mainly developed) countries. It is important to understand these obstacles and the impact that they might have on a measure's implementation viability.

Sustainability

The sustainability of the freight transport system in South Africa is questionable, as the country is highly dependent on foreign oil imports and mainly one mode of transportation (road). The transport sector is 98% dependent on petroleum fuels (DME, 2006), leaving it highly exposed to the risks of an oil peak and fuel price spikes. Diversifying the energy supply for transport will

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improve sustainability, but Eskom has warned that electricity supplies will continue to be under severe pressure until new base load capacity comes on stream from 2012 onwards (Hendler et al., 2008b). It would, thus, not be viable for the transport sector to increase its share of electricity consumption significantly in the short to medium term, without substantial sacrifice or efficiency gains in other electricity demand sectors. It is imperative that measures implemented improve the sustainability of the current system and not foster the high risk status quo even further.

Monetary obstacles

South Africa is a developing country that cannot afford to invest in obsolete development initiatives, to reinvest in the unsustainable practice of the past, or to invest in superfluously high-tech development alternatives. Poor historic monetary policy has led to disputes between various transport modes regarding equity in the recovery of infrastructure provision, management, operation, and maintenance costs (DOT, 1996). Measures that do not ensure an equitable distribution of infrastructure cost recovery (including the capital, management, operation and maintenance thereof) will likely bolster the artificial modal shift and distorted tariff structures created by cross-subsidisation.

It is vital to consider the externalities associated with a particular measure, as externalities are often not attributed properly. An example of this is the hidden externality costs of road freight, such as road infrastructure and environmental damage, accidents and congestion. These externalities are seldom reflected in the cost of freight transport.

The Minister of Transport, Jeff Radebe, announced in September 2007 that the country faced a R17 billion deficit for road maintenance over the following five years, covering nearly 15% of the national road network (Fin24, 2007). Clearly, the maintenance of roads is a major problem in South Africa. The impact of the implementation of a measure (for example, increased vehicular loads or load consolidation) on the maintenance of the freight network needs to be taken into account.

Infrastructure

Integration between the South African first and second economy is a high priority to the national government (CSIR, 2006; DOT 2005). This will require some investment in the freight network serving the rural areas of the country. Spending can, however, not be limited to these areas alone, as the primary network is also in desperate need for expansion. “Our infrastructure is inappropriate for the development path of our country, and needs to be revamped in order to prevent the perpetuation of our existing problems.” (DOT, 2005)

The Department of Transport (2005) indicate that the problem of current under investment in road infrastructure (only 50% of what is required) is coupled with a growing demand for freight transportation. Although sufficient in the primary sector, 38% of roads fall in the poor to very poor category, compared to an international benchmark of 5% to 10% (DOT, 2005). Additionally, all South African ports face the challenge of infrastructure development to accommodate the growth in international trade (Hendler et al., 2008a). Situma (2007) mentions that rail infrastructure has been poorly maintained and is in a general state of disrepair - having had little investment in its upkeep for about four decades. The traditional lack of investment in new infrastructure has hampered development and as a result, many improvement measures will require significant infrastructure investment. This is very expensive and has a long lead time.

Capacity issues and bottle necks

Capacity issues exist in all modes of freight transport. Masango (2004) identified four main system level bottlenecks in South African freight transportation as: a lack of adequate rail operational and infrastructure capacity and efficiency, port congestion, customs clearance procedures and border post delays. However, the greatest capacity issues, by far, lie with the railways. Whilst some corridors are close to capacity, the operational capacity on the Durban-Gauteng corridor is approximately 20% of the installed capacity (DOT, 2005), for example. A total of 15% of the rail infrastructure has no service, is closed or are operating as leased lines (Hendler et al., 2008a). It is believed that there is sufficient under-utilised infrastructure to permit the promotion of train operator competition over a large proportion of the network, but this will require the separation of track provision and maintenance from train operations (Hendler et al., 2008b). Due to poor wagon fleet renewal practice, old rail wagons with reduced payloads exist in substantial numbers, limiting the railways' ability to carry extra tonnage (Hendler et al., 2008a). In addition, the rail lines are narrow gauge, which limits their efficient carrying capacity. In terms of road haulage, South Africa currently permits some of the largest vehicle combinations in the world for general freight haulage (Hendler et al., 2008a). These vehicle carrying capacities and dimensions are a contributory factor in making road transport more competitive with rail transport.

Port capacity is extremely limited and prohibiting (DOT, 2005). Air freight is predominantly carried in passenger aircraft, which limits the carrying capacity per flight. This leads to limited spending on airport infrastructure that can accommodate more air freight (DOT, 2005). The pipeline network was operating at capacity on the Durban–Gauteng corridor in 2006, resulting in large volumes of petroleum products having to be transported by road and rail (Hendler et al., 2008a). A new pipeline has been commissioned and is due to come online in 2010. There are, however, some concerns that Gauteng's fuel demand will outstrip supply capacity before 2010.

Improvement measures aimed at alleviating pressure on bottlenecks and capacity constraints should enjoy high priority.

Equipment, technology and facilities

South Africa is below par when compared to international freight transport best practice. This is attributable to insufficient equipment, technology and facilities. For instance, the average age of a South African locomotive is 25 years, whereas the international best practice average is around 16 years (DOT, 2005). This situation also applies to wagons, signalling equipment and the rail tracks. Much of the nation's rail rolling stock needs replacement soon (Situma, 2007). The main reason for rail's poor operational performance is said to be due to the poor condition of its asset base (DOT, 2005).

Commercial vehicles in South Africa tend to be very old with long replacement cycles. Naamsa's annual report (2007) states that more than 42% of all commercial vehicles are 10 years old or older. Between 80% and 90% of South African air freight is moved by passenger aircraft (termed belly freight). Internationally, the split between belly freight and dedicated freight aircraft is around 50% (DOT, 2005). Port productivity is low, compared to international standards, due to the use of old equipment, limited technology and a lack of competition (DOT, 2005). A lack of proper inter-modal facilities between ports, road and rail, is the main inhibiting factor for growth in containerised traffic (CSIR, 2007).

Measures dependent on a high-tech freight system or modern equipment and facilities will not be viable in the short to medium term, at least.

Skills shortage

It is widely reported that a skills shortage abounds in South Africa. The freight transport sector is no exception, as confirmed by the Department of Transport's (2005) admission that the skills of railway employees are lower than that of their international counterparts. This shortage can limit the level of sophistication of viable improvement measures, for example: intelligent transport systems might be too advanced to be readily adopted.

Lack of information

In 1996, the Department of Transport proposed the establishment, operation and maintenance of a land freight transport information system which should contain, amongst others, freight conveyance patterns and routes, domestically and internationally; types of goods on different routes; main origins and destinations and value and tonnages carried. Such a system should also provide for needs and growth forecasts. Although steps have been taken towards achieving this (e.g. the national freight databank), there is still weak information integration and access to the data is not readily available. The reliability of data is questionable. Measures that require large volumes of accurate data (in order to successfully plan implementation) are presently a risk in South Africa.

Institutional and regulatory structure

The South African freight operating environment is characterised by open competition on the one hand (road and air freight sectors), and monopolies on the other hand, which reduce the efficiency and value proposition to customers (ports and rail sectors) (DOT, 2005). The Department of Transport (2005) is concerned with this inappropriate institutional and regulatory structure, because it does not punish inefficiency nor does it reward efficiency. "It is structurally incapable of appropriately allocating external costs and raising efficiency." Monopolies presently extract huge margins without the necessary re-investment. Money is used to subsidise areas of loss and inefficiency rather than to grow capacity. "The present situation frequently prejudices South African road transport operators in particular and land freight in general." (DOT, 1996) Any measures which are dependent on a solid institutional and regulatory system, requiring functional regulation, as opposed to modal regulation, will only be moderately effective until these issues are resolved.

Ownership

The ownership of infrastructure plays a significant role in the success of the industry. The fact that various infrastructure is privately owned or owned by Transnet, prohibits cohesion, limiting the systemic operational improvements that can be achieved (DOT, 2005). An example of this is the parastatal organisation Transnet Pipelines, who manage the main petroleum product pipeline operation in the country. Their monopoly has resulted in high tariffs and delayed investment in infrastructure (Hendler et al., 2008a). Similarly, the Transnet responsibility for port planning and management deters private sector investment and has resulted in a situation where several ports are badly in need of further redevelopment, investment and modernisation, but are limited by the provision of capital under the control of central government (Hendler et al., 2008a). The viability of measures is related to the ownership of the infrastructure utilised.

Freight network legacy

Present day South Africa has inherited a legacy favouring road transport above all other modes. Due to the effect of simultaneous deregulation of the road freight industry and regulation of the rail industry, the road freight industry blossomed. Since 1997, virtually all growth in land freight transport has been captured by road transport (Hendler et al., 2008a). Advantages that road freight has over rail include: accessibility (many places are only accessible by motor vehicles), competition (resulting improved service, reliability, operations, equipment and competitive pricing) and no perceived need for cross-subsidisation. The average locomotive travels 7 500 km per month, while the average similar haul road vehicle travels around 18 000 km per month (Hendler et al., 2008a). This performance deficiency favours road transport. Moreover, there is sufficient spare road capacity to accommodate increased traffic in most (non-metropolitan) areas of South Africa (Hendler et al., 2008a).

Hesse and Rodrigue (2004) report that the social costs associated with road and air freight transport are much higher than those of rail and waterway freight modes. It can be concluded that a status quo favouring road transport above all other modes is not desirable, hence there is a clear need for modal restructuring in the country. The historic lack of integrated planning of infrastructure between various spheres of government, parastatal organisations, agencies and the private sector has ensured that the most appropriate and optimal infrastructural solutions are not always possible today (DOT, 2005). Measures leading towards modal, spatial and institutional integration must be encouraged, with special reference to corridor development strategies and modal and capacity utilisation (DOT, 1996). Fair competition within and between modes must be ensured and where possible, increased. In the 2004 State of Logistics report (CSIR, 2004) it is stated that "An overarching investment strategy should consider the hypothesis that road transport costs the economy more than rail transport. Greater efficiency in rail is therefore a 'second prize' compared to greater efficiency between road and rail."

Geography

South Africa is spatially challenged in terms of its freight transportation, with production and mining facilities in the hinterland and ports vast distances away, at considerably lower altitudes. Another disparity is that the movement of goods from Gauteng constitutes double the movement towards

Gauteng on the two main corridors (Hendler et al., 2008a). Areas in the hinterland that have no access to rail are highly exposed, with a danger that both people and assets could become stranded. Interventions that rely on fully loaded return trips are not viable, as are strategies that rely on a strong rural transport network.

Social issues

South Africa is a country severely afflicted by HIV/AIDS. The illness is especially prevalent under truck drivers (DOT, 2005), resulting in extremely high driver turnover. This only exacerbates the skills shortage in the country. Other social issues affecting freight transport include crime (hijacking) and trade union activity. Striking or protesting truck drivers can have devastating economic repercussions. The social climate in South Africa must be taken into consideration during the analysis of measure viability.

ASSESSMENT OF THE VIABILITY OF IMPLEMENTING MEASURES IN SOUTH AFRICA

Assessment criteria, scoring and methodology

In order to evaluate all measures fairly, a set of assessment criteria was developed (see Table 1). The 46 criteria used were mainly derived from the discussion in section 2. Each measure evaluated is assigned a score per criterion. Due to a lack of quantitative information, it was decided to use a scoring system ranging between -1, 0 or 1 for this multi-criteria analysis. The conditions for assigning scores are indicated in Table 1.

Not all of the incorporated criteria are necessarily equally important. It was, therefore, decided to apply a weighting to each criteria cluster (as is commonly done in multi-criteria analysis), in order to distinguish between more and less important factors affecting the viability of implementing a measure in South Africa. The weightings applied are based on the amalgamated ranking of criteria by several members of the Centre for Transport Studies. Should the analysis be used to inform investment decision making, it is advised that stakeholder input on criteria and criteria weights should be incorporated. The criteria clusters in Table 1 are arranged from most important to least important.

Weighted scores are ultimately tallied over all criteria clusters for each measure. Depending on the total score, a measure is classified as non-viable, doubtful, neutral, potentially successful or extremely promising. The ranges used for classification purposes are indicated in Table 2.

Sustainability and energy efficiency improvement measures

Measures can generally be divided into the following categories:

- Alternative fuels and propulsion systems (such as electricity, hydrogen, hybrid-electric propulsion, tubular freight, magnetic levitation and alternative jet fuels)
- Efficiency improvements (including improving vehicular design, improving maintenance procedures, influencing behaviour through travel demand management practices and introducing intelligent transport management systems)
- Infrastructure amendments (e.g. dedicated road space or railway upgrades)
- Network design (referring to land-use planning and developments or network lay-outs like hub-and-spoke designs)
- Policies and regulation (e.g. driving bans, tolling schemes or fuel rationing)

Table 1 – Assessment criteria and score allocation system

CRITERIA	SCORE ALLOCATION		
Effectiveness Criteria	**-1**	**0**	**1**
To what extent will overall energy consumption be reduced?	Somewhat	Moderate	High
To what extent will oil dependency be reduced?	Somewhat	Moderate	High
How long lead time is required?	Long (>5 y)	Medium (>1 & <5y)	Short (<1 y)
How long is the implementation period?	Long (>5 y)	Medium (>1 & <5y)	Short (<1 y)
Has the idea been tested elsewhere?	No	N/A	Yes
If the idea was implemented elsewhere, is it still effective?	No	N/A	Yes
What is the expected penetration rate? (as % of industry size)	<20%	>20%&<50%	>50%
Are the required resources available?	No	N/A	Yes
Will a paradigm shift in freight transport be required?	Yes	N/A	No
Is SA freight currently at the appropriate level of sophistication?	No	N/A	Yes
Will other sustainability of efficiency improvement initiatives be impeded?	Yes	N/A	No
Sustainability Criteria	**-1**	**0**	**1**
How long before reinvestment will be required?	Short (<5 y)	Medium (>5 & <15y)	Long (>15 y)
Are sustainable resources used or are there enough resources?	No	N/A	Yes
Monetary Criteria	**-1**	**0**	**1**
Will external costs be reflected and fairly attributed?	No	N/A	Yes
Will equitable infrastructure cost recovery be ensured?	No	N/A	Yes
Will implementation be expensive?	Very expensive	Moderately expensive	Not expensive
What is the risk of unforeseen expenses?	High	Medium	Low
How long will the payback period likely be?	Long (>10 y)	Medium (>5 & <10y)	Short (<5 y)
What will the magnitude of capital required be?	High	Moderate	Low
What will the magnitude of operational expenses be?	High	Moderate	Low
What will the magnitude of maintenance costs be?	High	Moderate	Low
Skills Criteria	**-1**	**0**	**1**
Will operators need to be skilled and educated?	Yes	N/A	No
Will operational skills be improved?	No	N/A	Yes
Capacity Criteria	**-1**	**0**	**1**
Will spare capacity in the freight system be utilised?	No	N/A	Yes
Will there be enough spare capacity in the system?	No	N/A	Yes
Will additional capacity be required?	Yes	N/A	No
Will capacity in the system be freed up?	No	N/A	Yes
Infrastructure Criteria	**-1**	**0**	**1**
Will new infrastructure be required?	Yes	N/A	No
Will existing infrastructure become better utilised?	No	N/A	Yes
Will the infrastructure to be developed aid both the primary and secondary economic development objectives?	Neither	Only 1 or N/A	Both
Operational Criteria	**-1**	**0**	**1**
Will new operating practice and procedures be required?	Yes	N/A	No
How will maintenance be impacted?	More required	The same	Less Required
Will unequally distributed loads between origin-destination pairs impede the effectiveness of the measure?	Yes	N/A	No
Equipment, Technology and Facility Criteria	**-1**	**0**	**1**
Will more modern equipment/technology/facilities be required?	Yes	N/A	No
Will additional equipment/technology/facilities be required?	Yes	N/A	No
Information Criteria	**-1**	**0**	**1**
Will large volumes of data be required?	Yes	N/A	No
If data is required, will accurate and reliable data be required?	Yes	N/A	No
Will data collection be improved?	No	N/A	Yes
Institutional and Regulatory Criteria	**-1**	**0**	**1**
Will fair competition in the industry be promoted or inhibited?	Inhibited	N/A	Promoted
Will a problematic institutional and regulatory system limit effectiveness?	Yes	N/A	No
Will current monopolies hamper implementation?	Yes	N/A	No
Inter-modal Criteria	**-1**	**0**	**1**
Will new inter-modal facilities be required?	Yes	N/A	No
Will inter-modality be enhanced?	No	N/A	Yes
Will modal restructuring in the country be supported?	No	N/A	Yes
Social Criteria	**-1**	**0**	**1**
Will negative social circumstances (HIV/AIDS, labour disputes etc.) negatively influence the effectiveness?	Yes	N/A	No
Geographic Criteria	**-1**	**0**	**1**
Will the spatial disparity be improved?	No	N/A	Yes

Table 2 – Score ranges used for measure viability classification

SCORE RANGE	VIABILITY CLASSIFICATION
< 0	Non-viable
> 0 - 10	Doubtful
> 10 - 20	Neutral
> 20 - 30	Potentially Successful
> 30	Extremely Promising

The term 'efficiency improvements' represents a vast array of diverse measures; hence it was decided to sub-divide the category into 9 separate categories. In total, 31 individual measures (spanning 13 measure categories) were assessed (see Table 3).

Table 3 – Summary of results

MEASURES	SCORES	VIABILITY CLASSIFICATION
Alternative fuels and propulsion systems	6.50	Doubtful
Efficiency improvements	20.03	Potentially Successful
OPERATIONAL IMPROVEMENTS	28.88	Potentially Successful
DRIVER/OPERATOR BEHAVIOURAL CHANGE PROGRAMMES	26.54	Potentially Successful
INTELLIGENT TRANSPORT SYSTEMS	24.63	Potentially Successful
TRAVEL DEMAND MANAGEMENT	22.09	Potentially Successful
VEHICLE DESIGN IMPROVEMENTS (all modes)	21.14	Potentially Successful
VEHICLE SIZING AND CONFIGURATION (all modes)	20.77	Potentially Successful
MODAL SHIFT	17.80	Neutral
OLD VEHICLE REPLACEMENT SCHEMES (all modes)	9.50	Doubtful
INTER-MODAL SOLUTIONS	8.92	Doubtful
Infrastructure amendments	14.42	Neutral
Network design	16.61	Neutral
Policies and regulation	-1.51	Non-viable

Assessment results

3 measures were found to be extremely promising, 10 potentially successful, 8 neutral, 6 doubtful and 4 non-viable. The individual measures that scored the best are vehicle maintenance improvements, route optimisation and vehicle scheduling and intelligent traffic management systems. Driving bans, fuel rationing, tolling schemes and hydrogen propulsion systems are all classified as non-viable measures.

Efficiency improvements scored the highest of all five main categories (see Table 3). Of the 9 sub-categories, operational improvements (such as matching vehicles to loads in terms of size and engine ability, maintenance practice improvements and route optimisation and vehicle scheduling) scored the best. It is followed by behavioural change programmes, intelligent transport systems (such as traffic management systems, intelligent speed control and adaptation and driver information systems), travel demand management, vehicle design improvements and vehicle sizing and configuration, respectively. Modal shift measures are classified as neutral, while the viability of old vehicle replacement schemes and inter-modal solutions is regarded as doubtful.

Network design and infrastructure amendments are neutral categories (see Table 3). The viability of alternative fuels and propulsion systems is generally questionable. Hybrid-electric propulsion systems are the most promising of all the alternative systems and are classified as potentially successful. Driving bans, fuel rationing and tolling schemes are considered non-viable policy and regulation measures. Forced preventative maintenance is considered a neutral policy and regulation measure.

It is important to remember that measures are assessed purely in terms of viability and not necessarily based on their potential impact, effectiveness, expected level of adoption or the ease of implementation. The most effective measures are, however, expected to be: hybrid-electric propulsion systems, intelligent freight transport management systems, route optimisation and vehicle scheduling, vehicle maintenance improvements and vehicle design improvements. Introducing tubular freight, land-use reorganisation, load consolidation and clustering of destinations are expected to be the least effective measures, due to low market penetration expectations and long lead time requirements. Of all measures with a long lead-time, advocating the use of local produce to reduce food miles scores the highest.

Intelligent transport systems, operational improvements, network design measures, load consolidation and clustering of destinations, vehicle sizing and configuration and forced preventative maintenance were rated highly sustainable. Fuel rationing is the least sustainable measure. The best measure, in terms of monetary criteria, is hybrid-electric propulsion and the worst hydrogen propulsion.

Measures were also assessed using equal weights - in order to determine the effect of the weighting criteria on the results. The results from the second analysis indicates 8 extremely promising, 9 potentially successful, 7 neutral, 3 doubtful and 4 non-viable measures. The four non-viable measures identified with variable and uniform weights are the same with each weighting. Route optimisation and vehicle scheduling and improved vehicle maintenance are classified as extremely promising measures in both assessments.

CONCLUSIONS AND RECOMMENDATIONS

On the whole, efficiency improvement measures are expected to be the most viable solutions for mitigating the energy demand and improving the sustainability of freight transport in South Africa. Measures that can be implemented and make an impact over the short to medium term are favoured, because such measures are associated with less uncertainty, lower risk, generally lower costs, greater ease of implementation and, therefore, a higher probability of success. It appears that the South African freight system is better suited towards measures that aim to remove excess in the system, than those requiring new investment, infrastructure or radical thinking.

Extremely promising individual measures include: vehicle maintenance improvements, route optimisation and vehicle scheduling and intelligent traffic management systems. These measures are highly sustainable, require little to no new infrastructure, have short implementation periods, are relatively inexpensive, can alleviate pressure on bottlenecks and capacity constraints and are associated with few externalities. Policy and regulatory measures (such as driving bans, fuel rationing and tolling schemes) are deemed non-viable and the viability of alternative fuels and propulsion systems is doubtful in general.

Not all assessment criteria are equally important. Weighting the criteria provides more conservative results, as fewer measures are ranked viable. The measures that are ranked most viable and least viable remain the same, whether criteria are weighted or not. This boosts confidence in the results of the assessment. It is, however, recommended that stakeholder input be obtained on the weighting of criteria and scoring of measures should the assessment be performed to inform investment decisions. An interim weighting of criteria within each cluster is also recommended.

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