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Study of ABC Paulista Exports and Imports Using Emergy Synthesis

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ABSTRACT

Urban conglomerates are the focal point of diverse activities, being them commercial, industrial, social, economic or politics. The urban community growth creates numerous changes in lifestyle, land value, energy requirement and consequent environmental stress. In this direction, research related to environmental sustainability of urban systems and the availability of natural reserves are of extreme importance. Emergy is a robust instrument to environmental accounting and covers both natural and human resources requirements to create goods and services. The evaluation through emergy synthesis of cities, states, nations and its core resources provides a large scale approach to the assessment of urban areas and can improve election of policies for public interest. This work employs the emergy synthesis methodology to assess the environmental sustainability of the municipalities that compose ABC Paulista, which is an assemblage of three municipalities: Santo André (SA), São Bernardo do Campo (SBC), and São Caetano do Sul (SCS. ABC Paulista is part of Greater São Paulo and is an influential industrial, technological and housing area that provides support to the surrounding urban structure. Automotive and chemical activities are the leading economic activities at these neighboring municipalities, but some environmental and economic variations are recognized. Outcomes confirm that ABC Paulista, as well as the three municipalities individually, is extremely dependent on imported resources, being not sustainable in the long term.

INTRODUCTION

Urban settlements are nuclei of various activities, which have an impact on the biosphere as primary users of resources and environmental services supplied from outside their borders. Cities demand space, people, matter, information and other resources for the diverse activities they hold, depending on a larger or limited intensity on activities undertaken in other regions. Among these activities, one can find the production of food, combustible and raw materials, water supply and treatment, solid waste handling systems, people instruction, and other activities that cannot be developed within the limits of the municipality. Sahely et al., (2003) point out that investigation on urban metabolism can contribute to solving urban ecological and environmental problems by highlighting the requirements that urban ecosystems place on numerous resources, and the pressure of discharged wastes on the environment in and around the urban ecosystem. The continuity of a city and its physical structure depend on the flow of goods and services into and out of it (Huang et al., 2009). Consequently, there must be a steady flow of energy, arriving from different places in the biosphere, in the form of substances, people, knowledge and others crossing the boundaries of the municipality. According to Ascione et al. (2009), a system constrained by external resources (be they renewable or not) is never "sustainable", though it can in some way be stable for a moderately long time, depending on the balance of the support flows from outside. The urban population increase causes remarkable changes in lifestyle, land use, energy demand and consequent environmental stress. In this way, studies associated to environmental sustainability of

urban systems and the availability of natural resources are of major concern. Through emergy accounting, it is possible to specify trade-offs between the municipality and the "external environment" in order to assess its sustainability, and to evaluate the real wealth of a region with a more realistic approach than the vision proposed by the economic analysis of gross domestic product or the social analysis performed by the human development index. Since cities are particular ecosystems (Odum et al., 1995), there is a call for a broader view of resources and environmental services provided by the biosphere to their continuity.

The effectiveness of emergy accounting has previously been examined by many researchers for the examination of urban systems. Emergy assessment of states, nations and their resource basis grants extended view to appraisal of environmental areas and supports policies for public benefit (Odum, 1996). Ascione et al. (2009) investigated the sustainability of Rome and confronted with the sustainability conditions of Italy, and a model for integrated regional studies through a spatial analysis based on emergy in the province of Cagliari in Italy was developed by Pulselli et al. (2007). Zhang et al. (2009) examined the metabolism of Beijing, an Lei et al. (2008) assessed the dynamic urban composition and the economic growth of Macao. Huang (1998) has developed standards of urban sustainability indicators for Taiwan. Vega-Azamar et al. (2013) evaluated the environmental sustainability of the Island of Montreal in Canada using data from 2005.

The group of three municipalities named ABC Paulista is composed of Santo André (SA), São Bernardo do Campo (SBC), and São Caetano do Sul (SCS). The ABC Paulista is an outstanding industrial, technological and residence area that gives support to Greater São Paulo. The municipalities of ABC Paulista added 4.8% of the GDP to the state of São Paulo, and almost 3% to the Brazilian GDP in the same year. SBC occupied 13th position and SA 29th position in the Brazil's GDP rank (IBGE, 2009). These figures show the importance of ABC Paulista in the economy of the state of São Paulo and in the country. The region is also an essential supplier of natural resources to other municipalities, being the Billings dam, partly located in SA and SBC, one of the principal water reservoirs that provide water to Greater São Paulo.

The sustainability of regional development with regard to urban agglomeration is regularly connected with the performance of individual cities and their interactions with each other (Cai et al., 2009). Interchange between subsystems with competing goals is seen today as a critical determinant of system sustainability (Higgins, 2003). From the viewpoint of regional development, these grouped cities share the similar climate condition, infrastructure facilities, and the comparative value of clustering of industrial activities, but they also compete for local resources and market.

This work applies the emergy synthesis methodology to account and identify the essential inflows and outflows that cross the boundaries of ABC Paulista. With this accounting, the environmental sustainability of this group of municipalities is assessed, through an approach able to embrace economic and environmental aspects.

METHODOLOGY

The emergy accounting was performed based on the tables from National Environmental Accounting Database (NEAD, 2000); as described by Sweeney et al. (2007). The energy of renewable resources and the flow of imported and exported resources were obtained from governmental institutions websites and from the city council. (IBGE, 2011, 2012, 2013; CRESESB, 2010; SECEX, 2011; SEADE, 2011, City council web sites of each municipality.) The UEVs used are based on the approximate planetary baseline of 15.83×10^{24} sej/year (Odum et al., 2000).

In the study of countries, states, counties and cities, often some information, being them economic, environmental or social, become more and more scarce the smaller is the system. Due to the lack of local information regarding each municipality of ABC Paulista, the Shift-Share analysis tool has been employed as a way to quantify the exchanges between ABC Paulista and Brazil (Sevegnani, 2013; Heilbrun, 1981).

System description

ABC Paulista is part of the 39 municipalities that form Greater São Paulo, a large metropolitan area located in the state of São Paulo in the Southeast region of Brazil. Located almost in the center of the largest metropolitan area in South America, it has a total of 596 km^2 with approximately 43% of green area, and a population around 1.640 million people (IBGE, 2009). The economic development of the ABC Paulista was primarily due to the presence of the automotive industry, which has started around 1920 and still remains as a significant industrial activity. A prosperous chemical industry supports the demands of the automotive and other industries at the surrounding municipalities.

Services that come from inside Brazil were calculated using the Shift Share analysis (Sevegnani, 2013; Heilbrun, 1981). Workers supplied by other municipalities (direct labor) were accounted combining data of Census 2010 published by IBGE (2013). Detailed calculations for fuels, electricity, treated water and food are available on request.

RESULTS AND DISCUSSIONS

Figure 1 shows the energy systems diagram of ABC Paulista. The diagram shows the renewable natural resources (rain, wind and sun) that feed the ABC Paulista (urban areas, agricultural areas, industrial activities), and storages (water reservoirs, standing tree biomass, built environment). The diagram also shows physical components and economic sectors, as well as, their interactions through pathways of exchanged matter and energy flows, providing a preliminary picture of the internal complexity and dynamics.

The Billings dam is partially located at SA and SBC supplying water to various municipalities in the region of Greater São Paulo, including SCS. The water consumed from this storage was considered a renewable resource (R). The municipalities purchase resources from outside their borders and these resources (F) are shown in the upper part of the diagram (water, fuel, electricity, machinery, products

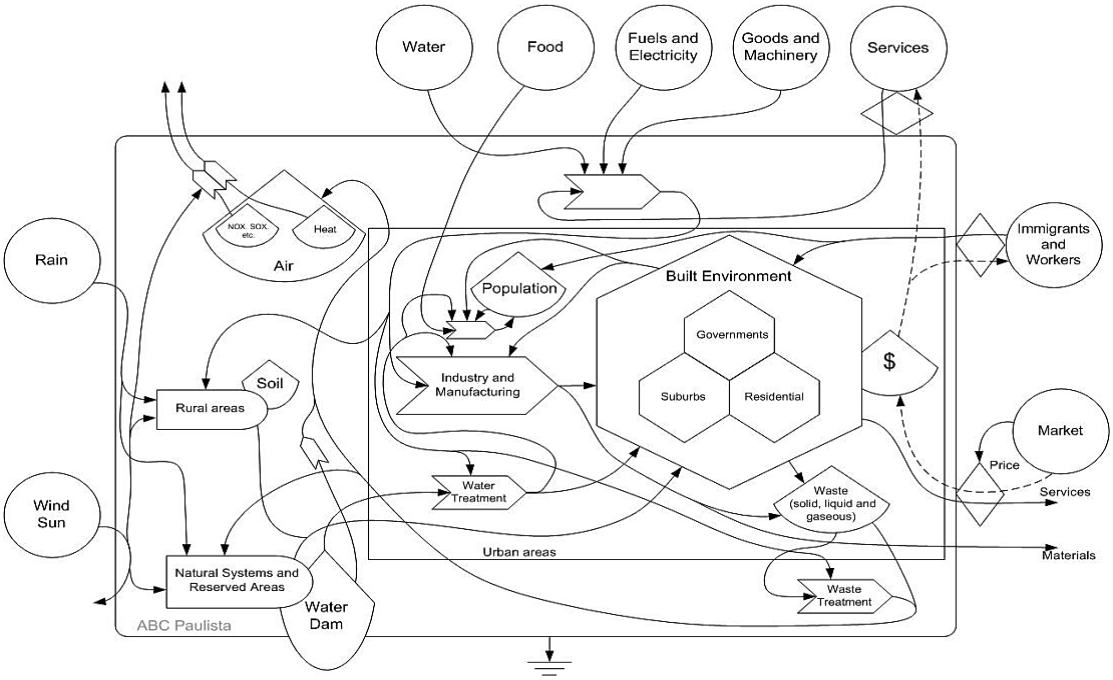

Figure 1. *Energy system diagram of ABC Paulista.*

and services). On the right side of the diagram are illustrated the financial transactions among municipalities and foreign markets. Within the outer limit of ABC's diagram, the infrastructure of urban activities represented by built and natural systems is shown. There are also activities related to provide water treatment and waste disposal. Industrial and manufacturing activities use the built environment yielding products and services that are exported to other locations. All these activities generate a stock of capital that is represented within the studied system.

In spite of the diagram be integrated for the three neighboring municipalities, some differences may be highlighted. The first regards to the industry activity profile. SA holds an industrial activity more focused in the chemical sector while SBC and SCS convene the automotive industry. Regarding the municipality structure, both SA and SBC hold urban and rural areas, whereas SCS is surrounded and limited by the urban growth of the capital (São Paulo) and other highly urbanized centers. SCS does not have rural areas and currently has no place for expansion other than vertical growth. The 0.14% green area results from urbanization projects.

Table 1 shows the emergy accounting for each municipality and for ABC as a whole. It is clear that ABC is not self-sufficient and depends on resources that come from Brazil and other countries. Imports were divided into those that come from inside and outside Brazil. It is interesting to note that imports from foreign countries contribute in a similar share to the total emergy of ABC (48.6% sej/sej) of those imported from Brazil (51.2% sej/sej), and this is due to the high use of imported resources by the industrial sector. It is also remarkable that 37.5% of the total emergy of ABC is associated to the services embedded in the imported goods, suggesting that the activities in the ABC Paulista generate considerable wealth in other parts of Brazil and the world.

Exports were also divided into those, which are sold in Brazil (52.5%), and those that are sold directly to other countries (47.5%). The main products exported to other countries are provided by the chemical (plastic and textiles) and automotive (machinery and metals, with 321×10^{19} sej/year) sectors. This result confirms the nature of these urban settlements that, despite accommodate people, housing and other activities common to other urban centers, mainly act as an industrial intermediary step where materials are assembled or processed into finished products that are in turn redistributed. ABC imports 4.1×10^{21} sej/year to maintain its structure (population and industrial sector activities) and exports 2.2×10^{21} sej/year in goods and services.

Table 1 also shows the emergy flows of each municipality of ABC that as a whole imports 99.7% of its total emergy. The main inputs of imported goods are the flow of electricity (19.0% in SA, 11.6% in SBC and 16.2% in SCS) followed by fuels (11.3% in SA, 6.6% in SBC and 8.8% in SCS).

Services, a money-based measure of indirect labor supplied and related information and know-how, indicate an emergy flow that is not directly linked to technology and raw resources. While technologies such as automotive assembling or chemicals production are similar worldwide, especially in times of globalization of markets, the same does not apply to services, which are largely different depending on a country's resources and economy. Services associated with imports account for about 31% in SA, 48% in SBC and 36% in SCS, and most of which is supported by non-renewable emergy flows (that is, non-renewable flows driving the economies of Brazil and other countries from which services were purchased). It is interesting to note that in regard to services inside Brazil, both SA and SBC depend on imported services, while SCS exports services to the surrounding regions.

The Analysis of ABC's Imported Resources

SA uses about 99.8% of purchased resources, SBC about 99.6%, while SCS reaches almost 100% of resources that come from other regions. All three municipalities are highly dependent on the import of agricultural products, electricity, fuels and labor from other regions of Brazil.

Table 1. Matter, energy and emergy flows supporting ABC Paulista and its municipalities.

	Item	Emergy (sej/year) (x 10^{19})			
		Santo André	**São Bernardo do Campo**	**São Caetano do Sul**	**ABC as a whole**
	Local renewable resources				
1	Solar radiation	0.08	0.18	0.01	0.26
2	Rain (Chem. energy in green areas) (*)	2.38	7.25	0.00	9.63
3	Rain (Chem. energy of run-off) (*)	0.01	0.02	<0.01	0.03
4	Rain (Geopotential energy) (*)	0.39	0.74	0.05	1.18
5	Kinetic wind energy	0.08	0.19	0.01	0.28
6	Geothermal heat	1.73	4.01	0.15	5.89
7	Water use from Billings dam	0.31	3.38	0.00	3.69
8	Evaporation	0.01	0.30	0.00	0.35
	Total of renewable resources (**)	**2.76**	**7.98**	**0.15**	**10.89**
	Local non-renewable resources				
9	Topsoil loss	<0.01	0.01	<0.01	0.02
	Total of non-renewable resources	**<0.01**	**0.01**	**<0.01**	**0.02**
	Imports from inside Brazil				
10	Fuels (Total)	164.57	150.96	34.31	349.84
11	Electricity (Total)	276.23	264.04	63.08	603.35
12	Treated water	6.43	6.98	1.98	15.21
13	Food	44.08	53.08	9.95	107.11
14	Services from inside Brazil	99.05	43.12	0.00	133.15
15	Agriculture goods from inside Brazil	141.06	157.43	32.81	331.30
16	Labor	261.95	234.14	68.47	564.56
	Total of Imports from inside Brazil	**993.35**	**909.77**	**210.60**	**2,104.51**
	Imports from outside Brazil				
17	Main food items (Total)	1.16	65.30	25.63	92.09
18	Metals (Total)	3.64	47.27	0.76	51.66
19	Chemicals	12.23	3.19	0.12	15.54
20	Cement	0.14	0.11	0.03	0.28
21	Rocks	0.00	0.00	0.00	0.00
22	Paper and derivatives	4.20	7.83	0.03	12.07
23	Plastic	53.19	30.29	0.99	84.46
24	Textiles	22.44	39.67	0.35	62.46
25	Glass	0.00	1.07	0.15	1.22
26	Machinery	6.59	114.71	12.65	133.95
27	Wood	0.00	0.05	0.01	0.06
28	Cotton	0.00	0.35	0.00	0.35
29	Services of imports from outside Brazil	356.22	1,047.72	138.92	1,542.85
	Total of imports from outside Brazil	**459.81**	**1,357.56**	**179.64**	**1,997.00**
	Total of imports	**1,453.16**	**2,267.33**	**390.24**	**4,101.51**
	Exports to outside Brazil				
30	Main food items (Total)	0.09	3.71	3.84	7.64
31	Metals (Total)	0.00	0.00	0.00	15.22
32	Chemicals	6.52	4.32	0.12	10.96
33	Cement	0.00	0.48	0.09	0.57
34	Rocks	0.00	0.00	0.00	0.00
35	Paper and derivatives	0.00	0.64	0.01	0.66
36	Plastic	151.22	34.64	7.32	193.18

	Item	Emergy (sej/year) (x 10^{19})			
		Santo André	**São Bernardo do Campo**	**São Caetano do Sul**	**ABC as a whole**
37	Textiles	148.13	10.35	0.80	159.28
38	Glass	0.00	2.80	0.08	2.89
39	Machinery	4.30	246.21	55.55	306.06
40	Wood	0.00	0.71	0.13	0.83
41	Cotton	0.00	0.00	0.00	0.00
42	Services of exports to outside Brazil	125.72	454.96	38.50	620.95
	Total of exports to outside Brazil	**444.81**	**763.85**	**107.80**	**1,318.23**
	Exports to inside Brazil				
43	Exports of industry to inside Brazil	323.72	369.18	56.78	761.80
44	Exports of services to inside Brazil	0.00	0.00	3.96	0.00
45	Labor	287.50	313.87	83.45	692.30
	Total of exports to inside Brazil	**611.22**	**683.06**	**144.19**	**1,454.10**
	Total of exports	**1,056.02**	**1,446.90**	**252.00**	**2,772.33**
	Total Emergy	**1,455.93**	**2,275.32**	**390.39**	**4,112.31**

(*) Rain was calculated as the sum of items 2 and the greatest value between items 3 or 4.
(**) The total of renewable resources was calculated comparing the emergy value accounted for rain (explained above) with the sum of items 1 and 6. The greatest value between these two values was considered the total of renewable resources.

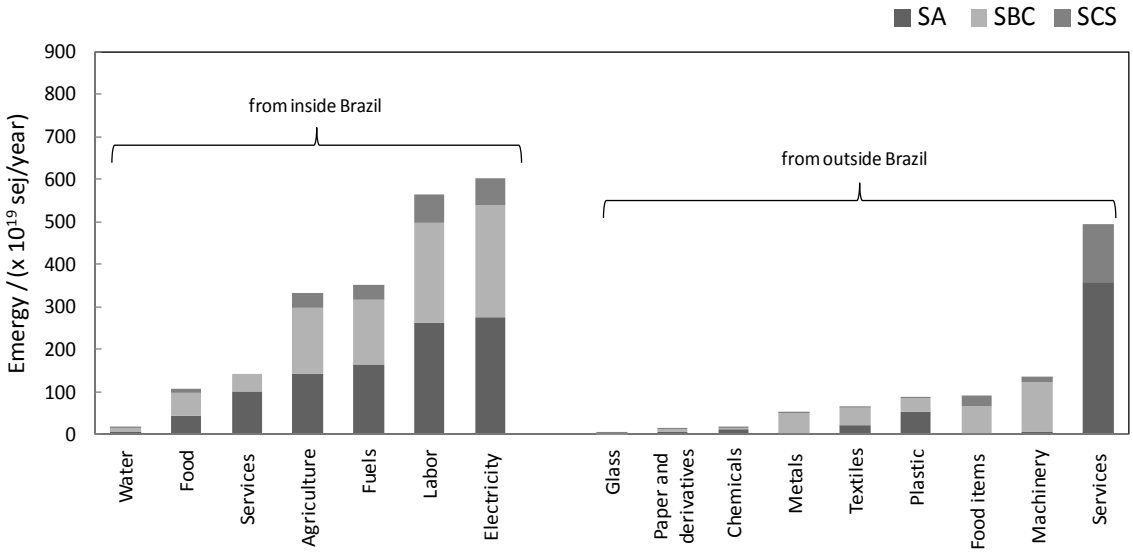

Figure 2. *Emergy signature of the imported resources for Santo André, São Bernardo do Campo, São Caetano do Sul and ABC.*

The dominance of Brazilian-controlled input flows (fuel, goods, labor, and services) is impressive, not only compared to locally available free renewable and non-renewable resources (Table 1), but also with materials and goods imported from foreign countries. Since none of the three municipalities count with natural reserves of raw material to be used in industries, it was assumed that exports depend on the resources (materials and energy) that enter the municipalities, and are transformed within their boundaries with the aid of local or imported labor. Results shown in Fig. 2 make clear that converting raw materials imported from outside the country depends on local availability of huge amounts of fuel,

electricity and labor. In regard to the resources that come from outside ABC, services embodied in the imports from outside Brazil contributes 37.5% to the ABC's total emergy making clear the industrial activities in the ABC generate extensive prosperity in other countries.

The Analysis of ABC's Exported Resources

Exports refer to selling goods and services produced to other markets, and are a measure of the total physical movement of goods and services out of each municipality. The emergy of total exports corresponds to almost 68% of the ABC's total emergy. SA individually exports 69.2% of its total emergy, SBC 62.2% and SCS 60.8% (Table 1). SBC exports 62.2% of its total emergy with a GDP of 1.45×10^{10} USD per year, while SA exports 69.2% of its total emergy with a GDP of 7.35×10^{9} USD per year. This result may indicate that energy and materials are used in the municipality, but also that products and services exported have low economic value. SBC exports 1.25 times more emergy in goods and services than SA (Table 1). SCS exports 60.8% of its total emergy, and the money received for exports corresponds to 1.13×10^{9} USD per year (Table 2).

The emergy signature shown in Fig. 3 gives a better view of all the other exported goods. It is shown that the major exports of ABC to outside Brazil correspond to machinery (more concentrated in SBC), plastic goods (more concentrated in SA) and textiles (more concentrated in SA). In the machinery sector, SBC responds to almost 89% of exports of ABC as a whole (to outside Brazil). When it comes to plastics and textiles together, SA responds to almost 85% of exports of ABC, accordingly to the main characteristics of the industrial activity held in each municipality. SA has as its major exported product (25% of total exports) tires for buses or trucks followed by tires for automobiles (12% of total exports). SBC has as its major exported product (13% of total exports) chassis with motors for vehicles that transport more than 10 people followed by automobiles (9% of total exports). SCS has as its major exported product (24% of total exports) automobiles with motors between 1500 and 3000 cm3 followed by automobiles parts (8% of total exports). Considering labor and services embodied in the exports, it is significant that ABC still exports more than imports.

Table 2. Emergy trade ratios (ETR) of Santo André, São Bernardo do Campo, São Caetano do Sul & ABC.

	Santo André	**São Bernardo do Campo**	**São Caetano do Sul**	**ABC**
GDP (USD/year)	7.35×10^{09}	1.45×10^{10}	4.46×10^{09}	2.63×10^{10}
EMR (sej/USD)	1.98×10^{12}	1.58×10^{12}	8.75×10^{11}	1.56×10^{12}
Emergy of total exports (sej/year)	1.01×10^{22}	1.42×10^{22}	2.37×10^{21}	2.77×10^{22}
Money received by total exports(*)	2.27×10^{09}	5.24×10^{09}	1.13×10^{09}	8.84×10^{09}
Emergy of money received by total exports	4.49×10^{21}	8.28×10^{21}	9.54×10^{21}	1.38×10^{22}
Emergy of the GDP (sej/year)	1.46×10^{22}	2.29×10^{22}	3.90×10^{21}	4.10×10^{22}
Money received by internal exports (**)	1.64×10^{09}	2.35×10^{09}	6.94×10^{08}	4.87×10^{09}
Emergy of money received by internal exports	3.25×10^{21}	3.71×10^{21}	6.07×10^{20}	7.60×10^{21}
Emergy of internal exports	5.36×10^{21}	6.53×10^{21}	1.08×10^{21}	1.32×10^{22}
Money received by external exports (***)	6.35×10^{08}	2.89×10^{09}	4.40×10^{08}	3.97×10^{09}
Emergy of money received by external exports	1.26×10^{21}	4.57×10^{21}	3.85×10^{20}	6.19×10^{21}
Emergy of external exports	4.45×10^{21}	7.65×10^{21}	1.30×10^{21}	1.45×10^{22}
Emergy trade ratio (considering GDP)	**0.694**	**0.621**	**0.607**	**0.676**
Emergy trade ratio (considering total exports)	**2.247**	**1.715**	**2.485**	**2.009**
Emergy trade ratio (considering internal exports)	**1.651**	**1.759**	**1.779**	**1.737**
Emergy trade ratio (considering external exports)	**3.539**	**1.675**	**3.377**	**2.341**

Detailed calculations at Appendix

(*) Exports (internal + external) of the municipality or ABC to the rest of Brazil and the world.

(**) Exports (only internal) of the municipality or ABC to the rest of Brazil.

(***) Exports (only external) of the municipality or ABC to the rest of the world.

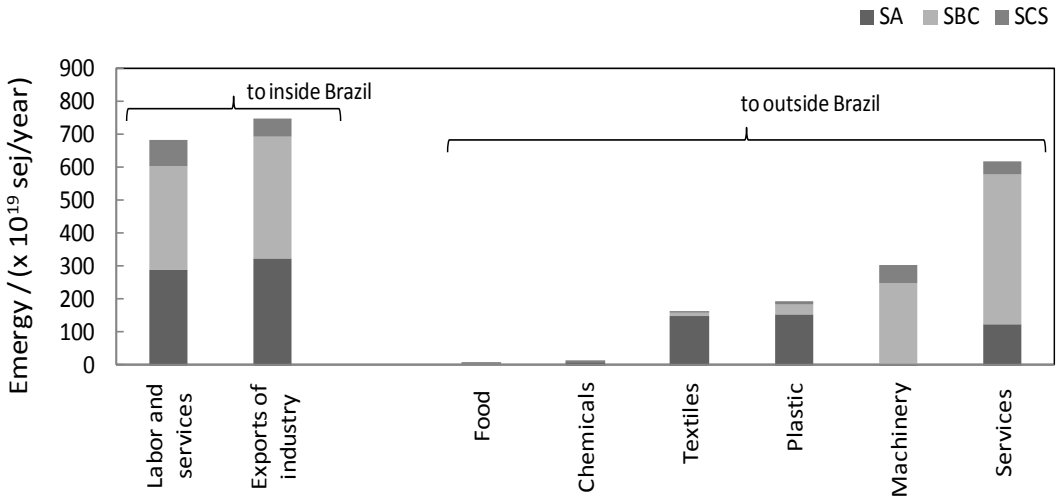

Figure 3. *Emergy signature of exported goods and services for Santo André, São Bernardo do Campo, São Caetano do Sul and ABC.*

By the observation of the percentages of exports, it is possible to suggest that the population of SCS is the one which makes the higher use of the resources it receives, both from nature and external economies. For the electricity use per capita value (Sevegnani, 2013), discounting the use of the industrial sector) and the value of the Human Development Index (HDI) (UNPD, 2000) is possible to suggest that the services exported by SCS are of highest quality. SA imports less service (31.3% of the total emergy) than SBC and SCS, which may indicate the availability to its own use or to export. SBC imports 47.9% of its total emergy and its exported services accounts for 20% of its total emergy.

As pointed out earlier, the economy of ABC can be considered as a subsystem of the state economy, functioning as a subsidiary economy within it. Materials and energy are imported, transformed and exported to the benefit to the greater systems (São Paulo, Brazil or abroad).

An emergy trade ratio (ETR) was calculated to analyze the emergy benefits that accrue to ABC as a result of exportation. Table 2 illustrates the comparison of all export emergy to the emergy of money circulating in these economies.

Considering hypothetically that all the money circulating in the municipalities is provided by exports, product emergy leaving the ABC was 2.77×10^{22} sej/year while the emergy of money circulating into the municipalities in exchange would be only 4.10×10^{22} sej for the same year. The emergy trade ratio for ABC would be 0.676. This indicates that if all GDP of ABC was composed by exports, the urban agglomerate would be investing 1 sej for every 1.48 sej received as emergy for money paid. In other words, in terms of emergy, ABC would be benefited by its exports. However, not all the GDP comes from exports. A much more real situation is achieved performing the same calculation using the real money received by the exports (Table 2).

In average, the money received by exports by the municipalities corresponds to 30% of their GDP. Thus, the exchange between ABC and the rest of the world are disadvantageous. The ratio, 2.009, indicates that ABC is exporting two times more emergy in goods and services than it is receiving in the money paid for them (Fig.4). The city that shows the smallest disadvantage is SBC and it is also the city which exports more services. For improving economic and ecological sustainability, ABC (especially SA and SCS) should consider alternatives to their current export profile including the development of industrial products that could deliver an emergy benefit.

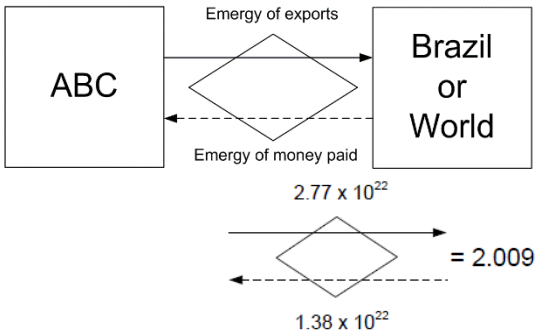

Figure 4. *Calculation of the emergy trade ratio for ABC considering total exports.*

Another point of view would be that, if the exports correspond roughly to 30% of the GDP, then the rest (70%) would be related to internal transformations. These transformations could be related to the production of goods and services destined to the local population's welfare.

Observing the emergy trade ratio considering only external exports and comparing it to the emergy trade ratio considering only internal exports it is noted that ABC has less disadvantage when trading with the internal market (Brazil), than when trading with the rest of the world. The emergy trade ratio of ABC for internal trading is 1.737. ABC delivers 1 sej and receives 0.575 sej when it exports to the Brazilian market, so Brazil takes advantage maintaining ABC's industrial activities ABC. When ABC exports to the foreign countries, the emergy trade ratio is 2.341, indicating that ABC should reconsider its trade with the external market. The relation between the delivered and received is now 1 sej to 0.427 sej.

The disadvantage found on trading with external markets can be partially explained by the values of EMR. Usually, Brazil buys from and sells to countries that have lower values of EMR, generally leaving the country in an unfavorable situation. On the other hand, the disadvantageous trade within the country was unexpected since EMR of Brazil is 3 times higher than that of ABC. Further studies considering the prices practiced in this trade are needed to explain the obtained result.

CONCLUSION

The complexity of this urban system is mostly driven by imports of non-renewables, which makes the system highly unsustainable and dependent on fossil fuels and a fossil fuel-based economy. In principle, such result is not new. However, converting raw amounts of resources into emergy units allows a comparison among flows of different natures and, most of all, changes the relative weight of flows compared to each other. Traditional energy or embodied energy evaluations only point out that the use of fossil fuels is very large, but are unable to quantify how large is the appropriation of environmental support and services by the urban system in the form of flows characterized by relatively lower energy content.

The evaluation of the emergy tables of the three municipalities that compose the ABC Paulista suggests that the cities underwent a process of auto-organization, in which each city has specific activities that may complement the activities of their neighbors. Together, the three systems support each other. SCS depends on the natural resources of SA, SBC and other neighbor municipalities, but provides services and housing for people who work in nearby cities.

The emergy accounting for SA, SBC and SCS have shown differences and similarities between them. These municipalities can be understood as emergy amplifiers. Raw materials or pre-assembled goods are received and transformed with the use of regional labor and services. Regional labor and services hold know how and are highly specialized, and the goods produced have higher transformities.

In general terms it is possible to affirm that the municipalities combine material and information that almost always come from outside its boundaries, in order to produce high quality products. There are actions that can improve their sustainability, but an urban system such as ABC will always require imported resources in a quantity much higher than its available local renewable and non-renewable resources.

The emergy trade ratio made clear that the actual result of ABC`s exports benefits Brazil and foreign countries. In this way, policies related to keep and maintain the Brazilian advantages may be maintained, but those that encourage direct export should be reviewed.

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APPENDIX

In this appendix are shown calculations and tables for the emergy trade ratio. ABC was taken as an example for the calculations. The same procedure was used for SA, SBC and SCS.

Emergy trade ratio considering GDP

$$ETR_{GDP} = \frac{\text{Emergy of total exports}}{\text{Emergy of the GDP}} \qquad EBR_{GDP\ ABC} = \frac{2.77x10^{22}}{4.10x10^{22}} = 0.676$$

Emergy trade ratio considering total exports

$$ETR_{tot.\ exp.} = \frac{\text{Emergy of total exports}}{\text{Emergy of the money received by total exports}}$$

$$ETR_{tot.\ exp.\ ABC} = \frac{2.77x10^{22}}{1.38x10^{22}} = 2.009$$

Emergy trade ratio considering internal exports

$$ETR_{int.\ exp.} = \frac{\text{Emergy of internal exports}}{\text{Emergy of the money received by internal exports}}$$

$$ETR_{int.\ exp.\ ABC} = \frac{1.32x10^{22}}{7.60x10^{21}} = 1.737$$

Emergy trade ratio considering external exports

$$ETR_{ext.\ exp.} = \frac{\text{Emergy of external exports}}{\text{Emergy of the money received by external exports}}$$

$$ETR_{ext.\ exp.\ ABC} = \frac{1.45x10^{22}}{6.19x10^{21}} = 2.341$$