A chemical waste management: reverse logistics partnership as a key to cost reduction

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Abstract
This study aims to analyze how a distinct production groups could work together to achieve logistical advantages in a waste management using exploratory case study in a printed circuit board manufacturing. The results show that partnership among PCB production and conventional galvanic process as a key for logistics cost reduction.

Keywords: Printed Circuit Board, Galvanic, Waste Management

INTRODUCTION

Nowadays, competitiveness is getting harder due to the continuous improvement needs, because, if the performance is not better day by day, the company takes the risk to loose market. In the past, product life cycle was longer than now and uncertainty was better controlled, this way being possible to get a good performance in activities that have been isolated inside an organization. However, there has been a gradual change and market, now global and in dynamic technological evolution, requires products with shorter lifecycle (Figueiredo and Arkader, 1998).

The technological evolution impacts in the business model, and consequently, the way to sell, done nowadays over the internet, replacing increasingly common ways by electronic transactions. It provides a market able to connect the whole supply chain, from industry and distributors to the end consumer, creating a new community, named e-business (Matera, 2012).

This new aspect, however, generates meaningful implications in the production process and leads the companies to the new strategies. Companies, working by themselves and looking for business in a limited geographical space, now can work in a marked much more spread than before. Then, the creation of a network between companies becomes a current practice and strategic to competitiveness and survival, and in this way a new organizational architecture is created, making innovation in relationship between companies (Olave and Neto, 2001).

These collaborative nets between companies could generate, in accordance to Nicolini (2001), what is named “Collaborative Logistics”, where companies that make part of the process to meet

demands from different logistic areas create a "collaborative chain", putting together multiple competences, making the difference in the companies' strategic plan, improving the win-win process besides reducing the gap between producers and customers, main roles in the supply chain.

According to Hashiba (2008), supply chain management studies highlight the partnership benefits, effective relationships between customers and suppliers whose impact leads to better financial performance and finally, higher profitability. It´s possible to note this relationship between companies that have a similar process, although far from each other in logistics management. One of the examples that will be addressed in this paper is the relationship between galvanic conventional process (for example, jewellery, anodizing) and Printed Circuit Board manufacturing.

Meneses and Assunção (2006) mentioned that in São Paulo, the most industrialized Brazilian state, a governmental program has been established prioritizing companies focused in continuous improvement in both water and air quality by effective pollution control. Surface finishing companies are also included in this program due to their potential to pollute.

There are common items in galvanic process from this kind of companies both in the supply of raw material and mainly in the waste generation, liquid and solid. Liquid waste is several times treated in the company and released to the sewage network. Its level of contaminants is regulated by Brazilian environmental laws, and it must be released in accordance to these levels. However, Balaton et al. (2002) says that galvanic solid waste generated after the liquid waste by galvanic industries offers more environment risks and additional costs to the generating companies because of its destination in landfills.

Therefore, this paper aims to verify the possibility of reducing costs and indirect logistics advantages by generating a strategic partnership between these distinct groups of production: Galvanic and printed circuit board manufacturers.

THEORETICAL FRAMEWORK

Galvanic is the process in which samples are covered to get protection against corrosion and handling besides offering beauty, resistance and improve surface properties to meet the requirements from the market (Costa, 1998; Mattos, 2011). In general, galvanic industry's waste is classified as hazardous waste, in according to the Brazilian law, due to its physicochemical or contagious properties. Such waste, when manipulated and managed inappropriately, can lead to environment damages as well as public sewage injuries. Pollution ways and contamination from galvanic comprehends from gas emissions to solid waste and liquid effluents, up to industrial effluent treatment station, that generates sludge (Santos and da Costa, 2009).

Galvanic Process activities generate a huge amount of liquid effluents. These liquids contain high toxic load, composed by metals like copper, chromium, tin, nickel, zinc, among others as well as cyanide compounds that come from electrodeposition process. These galvanic processes are applied to materials for decoration like sanitary metals, corrosion protective as well as surface finishing in several markets like automotive, aerospace and naval. There are different specifications that must be fulfilled in each industrial area, as well as critical items of control, affecting process features and its waste (Simas, 2007)

Printed circuit boards (PCB) manufacturing is composed by several mechanical, photographic and chemical process. Photographic processes, in essence, are also chemical because there is dissolution of polymers changed by laser or UV radiation, in the artwork fabrication as well as Dry film and Solder Mask development in a Sodium or Potassium Carbonate solution.

Therefore, the waste generated by PCI galvanic process is highly harmful for the environment. Electroless copper processes – still widely used in the PCB industry – contain formaldehyde, an organic compound in galvanic line, which should suffer an additional treatment process in a sewage treatment system, in order to remove the metals, increasing the treatment cost.

Furthermore, the surface preparation processes, as degreasers and deoxidizers, after saturation set by the companies engineering, still present concentration of such chemicals that could vary from 6 g/L to 20 g/L. These saturated baths made from acetic acid and persulfate are a source of metals in effluent treatment.

The effluent created by copper etching process, which is continuously renewed in horizontal processes, has a friendlier destination for the environment. This effluent is very rich in ammonia, very useful in fertilizer industry. These companies remove the copper present in the solution - that in some cases could reach 160 g/L – leaving the ammonia in solution, and then the fertilizer industry could use this effluent as raw material.

One of the more complex effluents to be reused is tin strippers based on nitric acid. This product entry in the sewage treatment system (STS) depending on the capacity and dimension of the system, can lead to a low treatment speed, preventing galvanic line to send waste, interrupting the treatment.

It´s worth noting that if the effluent for treatment doesn't receive the concentrated tin waste, it is composed manly by copper. Nonetheless, there are other contaminants and the sludge´s not allowed to be used like a pure copper that needs to be processed to become an input. This sludge´s destination also has its particularities as cost, quantity and mainly the suitable transportation logistics from the waste generators and companies that are going to process the residue.

Waste treatment

Despite conventional galvanic process uses a bigger variety of coatings like anodizing, galvanizing (using zinc), chroming and phosphating, the process applied to Printed Circuit Boards uses mainly the same basics of surface treatments like degreasers and deoxidization and also uses metallic deposits like copper, tin as well as gold in some cases. These similarities also happen in the waste generated by these business.

The effluent treatment is done by physicochemical treatment stations, generating at same time treated water and sludge. This material needs to be transported and changed in an inert material to be disposed suitably in the environment. In accordance to Mattos (2011), the sludge treatment process can be storage, landing, incineration, coprocessing, thermal plasma, microencapsulation and recycling.

Stocking consists in the waste storage, leading to a company´s environmental liability increase. Landing, albeit low cost processing, it doesn't solve the waste management problem, because environmental liability after encapsulation requires a high control, especially regarding the groundwater table from the landing area.

Sludge incineration makes possible the volume reduction but it doesn't remove the ashes destination needs, that must be stored in landfills because they are classified in according to the Brazilian law as hazardous waste. Alternatively to this process, there is the coprocessing, thermic waste destruction in cement ovens.

Thermal plasma promotes thermal destruction through an ionized gas. The high temperatures volatilize organics and fuse the metals, generating a vitreous matrix. It makes the waste to be inerted and used in a ceramic industry or steel mill. In according to Pinto (2012), the sludge is not

hazardous. It's an extreme economic importance because there is an exploration potential higher than in mines due to its high quantity of metals.

One of the best methods to have the sludge allocated is the coprocessing in cement ovens, which negative effects are noticed by people who live in the factory neighborhood, as well as who lives not close, but they are in the wind direction. These people are chemical composites receptors emitted by the companies and they are subjected to get illness, increased by cement factories and accidental risks, from spills to explosions evolving the waste.

The pollutants emitted by smokestack industries, specially clinker ovens create a layer in the air, and its dispersion in the atmosphere depends on the meteorological conditions – wind speed and direction, precipitation, thermal inversion – pollutant features and the source – speed, temperature, gas flow, smokestack height. During this process that makes the air polluted, chemical substances, gasses and particulates in the air could be inhaled or make contact to the eyes or skin leading to harm to human health.

An example that could work

In the 1990's, a São Paulo State Government program, named *Projeto Tietê,* aimed to detect and rule companies that throw pollutants in the river that cuts the city. Galvanic industry, known by its pollutant potential has been obligated to give immediate solutions to its effluents and waste. The goal set by the government was stopping polluting in a month.

In this context, in 1994 CENTRALSUPER has been created. It´s a company from employers' association called SINDISUPER, that started to receive the sludge from all the companies' members of the association.

Step by step, due to the sludge storage, it was possible to negotiate prices to a final destination in cement ovens or landfills. In 2003, a new treatment for sludge has been started. From a partnership between CENTRALSUPER and IPT (technological research institute) has been created a company called Ecochamas. This company, with technology developed to sludge treatment by plasma, had private and public investment.

Initially, the plasma machine should have been installed next to the waste generators, in São Paulo central area. However, the environment public agency from São Paulo didn't allow the installation due to the high population density, disregarding the support from the galvanic companies. Thus, Ecochamas has its factory installed in Resende, Rio de Janeiro state, and started its operations.

METHOD

From an exploratory study along with a case study and non-structured survey. This method helped to understand the state of the art of the galvanic waste treatment, and showed if there is a possibility to cost reduction in the sludge destination from galvanic companies and Printed Circuit Boards industry.

RESULTS

Modern techniques of operational research of supply chain as mentioned by Shapiro (2001), allow the integrated management of the entire phases of a productive process. It could be accomplished by SWOT approach showing the weaknesses and strengths of the integration in these

processes. Therefore, the results are going to be classified in according to technical, economics, organizational aspects as well as legal requirements of chemical logistics in São Paulo State

Technical Aspects

In this step it was done a comparison between waste from a surface treatment company and a Printed Circuit Board industry by chemical analysis. The sludge from a galvanic industry, for instance anodizing, is shown in the first column of the table 1. In the second column is shown the sludge composition from PCB industry.

Table 1 – Comparison between sludge composition - Source: [1]Simas, 2007; [2]Created by the authors

Parameters	Anodizing[1]	PCB[2]
Metal	mg/kg	mg/kg
Al	62,880	1,213
Ag	0	3
Ba	0	633
Cd	0	4
Ca	18,290	0
Co	0	0
Cr	10	2,313
Cu	10	206,266
Sn	0	264
Fe	1,140	0
Mn	0	354
Na	0	10,654
Ni	60	145
Pb	0	943
Zn	570	5,947

Organizational Aspects

According data from SINDISUPER, that is associated to FIESP, a São Paulo state representative of companies from every kind of industry, there are 89 galvanic treatment companies in the state, whose geographic localization is shown in the figure 1.

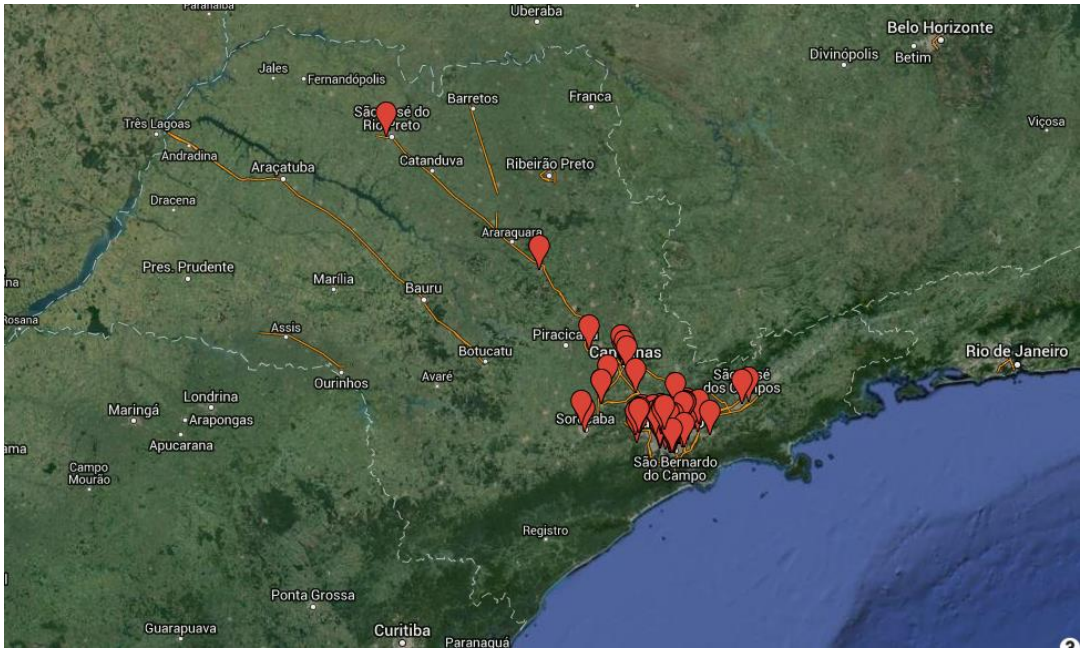

Figure 1 – Geographic Localization of surface treatment companies in São Paulo state – Source: SINDISUPER, 2016

Similarly, it´s shown in the figure 2 the geographic localization of PCB industries in São Paulo State.

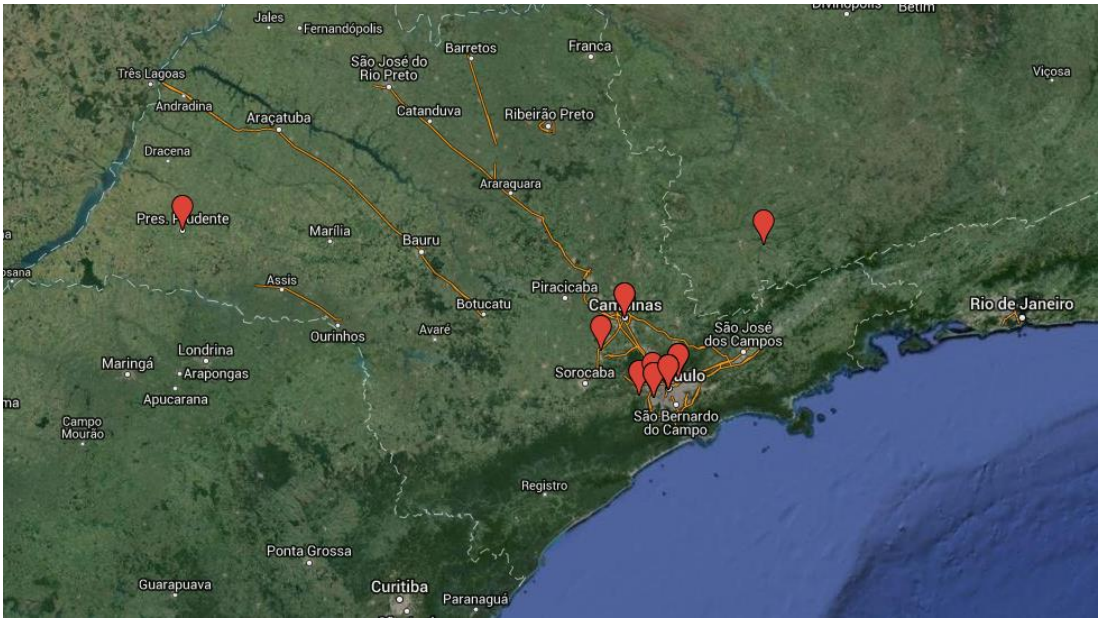

Figure 2 – PCB industry Geographic localization in São Paulo State – Source: ABRACI (2012)

It has been decided to include in this study a company in the south of Minas Gerais State, due to the relative position to the companies in São Paulo metropolitan area, in order to get advantages of an integrated logistics to waste management.

In the waste generation step, the sludge after segregation is stored or packaged to be dispatched for instance to the cement factory, to the incineration units or landfill disposal. The waste transportation requires the load preparation and special care in transport itself and material unload in the destination. If a cement factory is considered, the waste is temporarily stored and directed to the waste feed system of clinker ovens. (Sevá Filho and Santi, 2003).

Legal Aspects

A number of requirements specified by Brazilian technical standards must be fulfilled to chemical products transportation. In general, these standards specify suitable transportation equipments, the transport equipment conservation must be in a way that doesn't allow waste spilling or leaking. The waste must be protected from weather and suitable packaged. It can't be carried out with food, medical products and its packages. The transportation must fulfill the environment law, followed by the whole documentation required by the environmental public agency. Moreover, the transport equipment must be identified with the carried waste number.

Economics Aspect

Specialized companies in waste treatment and waste transportation have been consulted. To the company that makes the waste treatment there's no differences about the processing value if there is a bigger waste volume to be treated.

Regarding to the waste collection and transportation, it has been done a simulation of costs in 3 scenarios. For this, it's been chosen in a random way, two waste generating companies – named A and B – and the company whose waste would go to be treated.

The first scenario consists in the carrying waste from the company A to the waste treatment company. The second scenario is related to carry waste from the company B to the treatment and the third one from the company A, to the company B and in the last to the company that would receive the waste. It's been considered the same truck type. The volume doesn't matter to the freight value calculation. Table 2 shows the values in BRL.

Table 2 – Freight costs for each scenario studied

	First Scenario	Second Scenario	Third Scenario
Freight values	BRL 980,00	BRL 896,00	BRL 1,225.00
Values paid by each company	BRL 980,00	BRL 896,00	BRL 612.50

It´s a common practice the waste storage inside the factory installations until the maximum capacity truck transportation. With sharing, this storage could be reduced and the colleting could be done in less quantity each time. Therefore, the factory space occupied with waste is small, reducing risks with hazardous waste storage.

CONCLUSION

It's safe to assume that the waste generated by the PCB industry could be processed along with the sludge generated by conventional galvanic companies because they are complementary with a metal preponderant in each industry. It's been considered Aluminum for anodizing and Copper for

PCB industry, showing us the process basis of each industry as presented in the technical aspects section. Thus, the metals are compatible.

Nonetheless, regarding to the organizational aspects, the waste sending to the treatment companies in an individual way shows a risk higher than an integrated colleting. The proximity between companies allows the existence of a system that groups the collets and reduces the transportation risks, besides costs. If the organizational were related to the legal aspect, the distance between waste generators and treatment companies would impact in the logistic costs. Furthermore, the risk of accidents increase as the distance between start point and destination gets higher.

It must be considered that, even the integrated transportation costs aren't cheaper than the individual carrying, it's necessary that there is a minimum quantity of waste available to be picked. This leads to the space available in the industries to waste storage that, beyond the risks, there's a cost of occupied space by a product that won't be converted in value. Moreover, an integrated logistic process allows the transportation capacity inside the truck to be filled up as well as the waste treatment capacity.

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