Research on Cost Control of Hazardous Chemicals Enterprises - Based on the Perspective of Transport Service Chain Cost

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The cost control of hazardous chemicals enterprises is of great practical significance. Many experts and scholars have conducted studies in this issue before, however, existing researches tend to be based on the assumption of minimizing cost, ignoring the particularity of hazardous chemicals enterprises, that is, there is an inverse relationship between the cost control and the risks, the more the cost input, the lower the risks; the less the cost input, the higher the risks. In this context, based on the perspective of transport service chain of hazardous chemicals, this paper discusses the cost control of enterprises based on risk factors, and points out Hazardous chemicals companies should focus on three aspects, including storage operations cost management, transportation cost management and risk control cost management.

1. Introduction

Hazardous chemicals are important industrial raw materials. In recent years, the social demand for hazardous chemicals has been gradually increasing, and the number of enterprises engaging in the production, storage and transportation of hazardous chemicals also increases. Hazardous chemicals companies are facing many problems in their operations. The first is the high cost, the second is the poor corporate risk control (Sivakumar, 1993). It can be said that the prevention and control of risks are the responsibility and obligation of hazardous chemicals companies. However, due to the limitation of cost, enterprises have limited investment in risk control. Therefore, it is very important to study the cost control of hazardous chemicals enterprises so that more funds can be invest into risk control.

Many studies have pointed out that the major costs for hazardous chemicals companies are storage costs and transportation costs (Plüss & Ferrell, 1991; Bennett, 1996; Larsson, 2007), both of which can be included in the costs of the transport service chain studied in this paper. The purpose of this paper is to analyze the relationship between the cost of transportation service chain and the risks by analyzing the cost of transportation service chain of hazardous chemicals companies, then this paper puts forward some suggestions and methods for controlling and optimizing the cost of transportation, and provides references for cost control for the hazardous chemicals companies.

2. Hazardous chemicals transport service chain

For now, there is no standard definition for the service chain of transport of hazardous chemicals yet, but the definition of service chain is basically mature. The service chain is a consumer network based on Internet of Things technology (IOT), logistics technology and so on, with demand as orientation and various well-organized services (Brockhoff, 1992; Vanderstraeten, 1996).

According to above definition, this paper defines the transport service chain of hazardous chemicals as a consumer network based on modern science and technology with demand as its orientation and organically combines the services during the storage and transportation of hazardous chemicals. The participants in the hazardous chemicals transport service chain can be single agents or multi-agents (such as manufacturing enterprises, warehousing enterprises and transport enterprises). When the agents are diversified, different

agents have different responsibilities: manufacturing enterprises are responsible for producing goods; warehousing enterprises provide warehousing and handling services; and transportation enterprises provide transportation services (Guo, 2010; Reniers & Pavlova, 2012; Li, 2013).
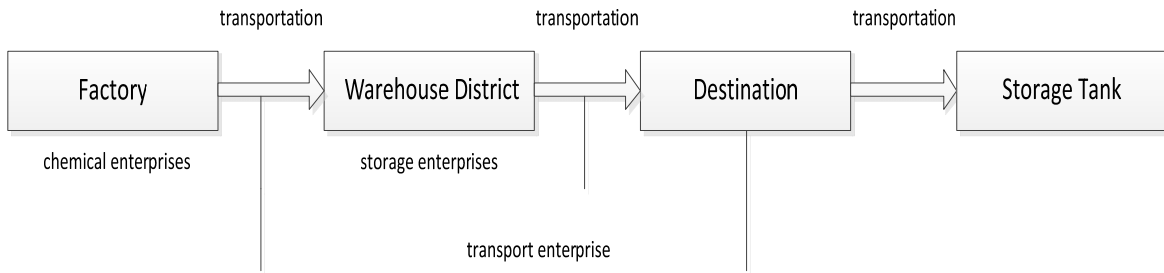

Figure 1: Dangerous Goods Transportation Service Chain

3. Hazardous chemicals transport service chain cost analysis

3.1 Definition of Cost of Hazardous Chemicals Transport Service Chain

The enterprise logistics cost refers to the monetary performance of materialized labor and live labor consumed in logistics activities (Erkut, 1995; San et al., 2003; Faghih-Roohi, 2016; Toumazis, 2013), it is the sum of all consumed manpower, materials and financial resources during the process of cargo transportation, storage, handling and processing.

With reference of this definition, and above-mentioned definition of the transport chain of hazardous chemicals, this paper defines the cost of hazardous chemicals transport service chain as follows: the cost of hazardous chemicals transport service chain is the sum of all consumed manpower, financial resources and materials during the process of storage and transportation, the cost can be divided into three categories: storage cost, transportation cost and risk control cost.

3.2 The cost composition of the transport service chain of hazardous chemicals

It has been pointed out above that the cost of transportation service chain can be divided into three categories, namely storage cost, transportation cost and risk control cost. Storage cost refers to the sum of all the costs of hazardous chemicals in the storage process, including warehousing, handling, moving, waste disposal, etc. (Leonelli, 2000). Transportation cost refers to the full costs incurred in the operation of transportation vehicles (mainly trucks, trains and ships) (Fang 2004; David 2013), including depreciation, maintenance, repairs, fuel costs, lubricant costs, etc. Risk control cost refers to the sum of all costs that are used for mitigating the risks (Karkazis & Boffey, 1995; Bonvicini, 1998), including the purchase and maintenance of monitoring equipment, the management costs associated with risk control, and so on.
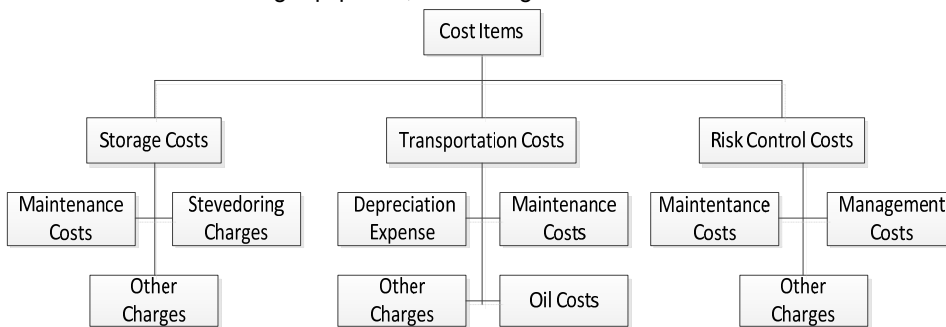

Figure 2: Cost Structure Diagram

According to the statistics of relevant associations, in the industry average, storage costs of hazardous chemicals companies account for about 20% of total costs, transportation costs account for 60% -70% of total costs and risk control costs account for 10%- 20% of total costs.

According to the relationship between cost and volume, the cost of hazardous chemical companies can also be divided into fixed cost and variable cost. According to the academic definition, fixed cost refers to the total cost of a certain period of time and within a certain volume of business, not subject to changes in business volume; variable costs refers to the total cost of production subject to changes in business volume. The cost

items of the change are mainly the value of raw materials, fuel, power and other factors of production. When the output increases for a certain period of time, the consumption of raw materials, fuels and power will increase correspondingly in proportion and the costs incurred will increase proportionally. Among the transportation service chain, the cost of transportation tools and the cost of testing tools are all fixed costs, while personnel costs, fuel costs and management costs are typical variable costs. In the process of cost control, fixed costs are hard to reduce in a short time, while variable costs are not. Therefore, when we talk about cost control and optimization, we mainly refer to the control and optimization of variable costs.
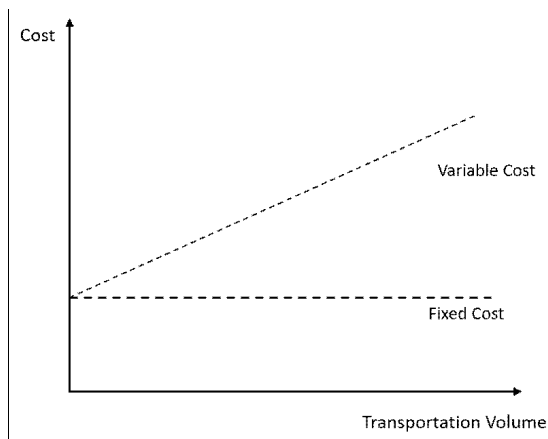

Figure 3: The Relationship between Cost and Transportation Volume

4. Hazardous chemicals transport service chain cost control methods

Many scholars have used models to explore the cost control of hazardous chemicals companies. However, all these models aimed at minimizing the cost and neglected the particularity of hazardous chemicals companies, that is, the special requirements of risk control. In this context, this paper explores the cost control of the transport service chain of hazardous chemicals based on the relationship between risk and cost.

4.1 The relationship between transportation costs and risks of hazardous chemicals

Among different costs of the transport service chain of hazardous chemicals, the storage cost and transportation cost dominate (Li, 2013; Torretta et al., 2017) and typically account for around 80% of all costs. For hazardous chemicals companies, the risk is not only about the risk control cost, it's also about the storage cost and transportation cost. Typical examples include the cost of repairing transportation vehicles, training cost for related personnel, cost of technical inspection, and so on. Generally speaking, the relationship between the above-mentioned cost inputs and enterprise risks can be summarized as follows: the higher the cost input is, the less the risk is likely to occur, the lower the cost input is, the greater the risk is likely to occur, and the marginal utility of cost input increases first and then decreases (Onishi, 1985; Jin & Karwan, 1996). The above relationship can also be understood as the level of risk control of enterprises rises with the increase of the cost. Therefore, the relationship between the cost input and risk of the hazardous chemicals transportation service chain is shown in the following figure.
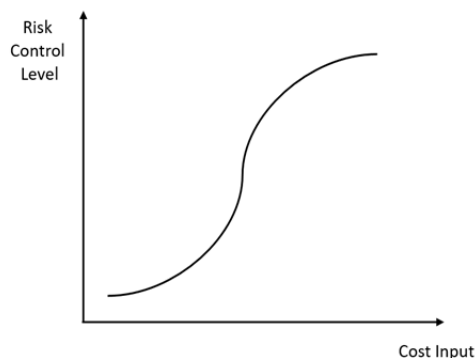

Figure 4: The Relationship between Cost Input and Risk Control Level

4.2 Cost structure optimization within acceptable risk range

Above analysis shows that the risk decreases with the increase of the input, meanwhile, the corporate profits will reduce accordingly; lower cost input may result increase in profit, but the possibility of risk also rises. Therefore, how to find the balance between cost, risk and enterprise profit is an urgent problem to be solved by the hazardous chemicals enterprises. In this section we will answer this question by modeling.

This paper establishes the formulas for each cost in the process of transport service chain of a hazardous chemical company.

(1) Storage Cost (C_S) can be expressed in the following formula:

$$C_S = P_Z \sum_{i=m}^{n} q_{iZ} + P_{J1} \sum_{i=m}^{n} q_{iJ1} + P_{J2} \sum_{i=m}^{n} q_{iJ2} + P_H \sum_{i=m}^{n} q_{iH} + \sum_{i=m}^{n} C_{iF} \tag{1}$$

Where, C_S is the total cost of storage operations in the i-th month; P_Z is the handling cost (yuan / ton); q_{iZ} is the handling volume (tons); P_{J1} and P_{J2} are two kinds of construction costs for warehousing and storage area respectively (Yuan / square meter), q_{iJ1} and q_{iJ2} are storage volume (square meters); P_H is port charges (yuan / ton), q_{iH} is handling service volume (tons); C_{iF} is fixed cost (yuan).

(2) Transport Costs (C_T) can be expressed in the following formula:

$$C_T = C_e + C_w + C_o + C_l + C_f = \sum_{i=m}^{n} x_{ie} C_i + \sum_{i=m}^{n} x_{iw} C_i + \sum_{i=m}^{n} x_{io} C_i + \sum_{i=m}^{n} x_{il} C_i + \sum_{i=m}^{n} C_{if} \tag{2}$$

Where, C_e, C_w, C_o, C_l, C_f respectively represent the spare parts, manpower, fuel, lubricant costs and fixed inputs in the transportation service, all units are Yuan. C_i represents the total cost of transportation service chain in the i-th month, and x_i is the ratio of each costs to total costs.

(3) Risk Control Costs (C_R) can be expressed in the following formula:

$$C_R = \sum_{i=m}^{n} x_{ir} C_i + \sum_{i=m}^{n} x_{im} C_i \tag{3}$$

Where, x_{ir} represents the proportion of risk control cost in the i-th month to the total cost, and x_{im} is the proportion of the risk cost of transportation equipment to the total cost.

(4) According to above formulas, the total cost of transport service chain can be expressed as:

$$C = C_S + C_T + C_R \tag{4}$$

In order to make the cost formula to achieve the minimum, we set the following constraints:

$$x_{ie} + x_{iw} + x_{io} + x_{il} = 1 - \frac{C_S + C_T + C_R}{C} \tag{5}$$

$$\sum_{i=m}^{n} x_{ie} C_i \geq (n - m + 1) N M_e \tag{6}$$

$$\sum_{i=m}^{n} x_{il} C_i > (n - m + 1) M_l \tag{7}$$

Where, N is the number of the means of transportation, M is the average monthly cost of spare parts per unit of the means of transportation.

In the process of solving the model, first we need to assume a sustainable risk value, and then adjust the proportion of other costs in the total cost. In the solution process, the above model actually controls the risk related costs (such as risk control cost, equipment maintenance and testing cost, etc.), by reducing other costs (including staff cost, fuel cost, lubricant cost, storage cost, etc.) to achieve the purpose of reducing costs without raising the risk.

4.3 Hazardous chemicals transport service chain cost control methods

According to the meaning of the model above, hazardous chemicals companies should mainly control variable costs, such as personnel cost, fuel cost and lubricant cost, and should not reduce various expenditures directly related to risks, such as equipment maintenance, testing expenditures, etc. Management believes there are some ways to reduce costs that apply to all businesses, especially for labour costs. For labour cost,

one method is to eliminate the redundant members. In addition, companies need to train their stuffs, which is not a small expenditure. Companies should focus on improving the quality of training, shortening the training cycle, reducing staff mobility, and improving the training effectiveness while reducing training cost.

In this article, we believe that hazardous chemicals are very special in some ways. In this context, the article will describe some specific cost control measures in detail.

(1) Storage Operations Cost Management

Firstly, hazardous chemicals companies should control labour costs. They should hire the people they need, not as many people as they can. Secondly, hazardous chemicals companies should make storage plans and do their best to avoid warehouse idleness. Operators should understand that the demand for different types of chemicals is seasonal, so they should adjust inventory according to demand. Last but not least, a large part of the expenditure of storage cost comes from the expenses of renting or purchasing land. Hazardous chemicals companies should ask for more preferential policies.

(2) Transportation Cost Management

As mentioned before, oil costs account for a large proportion of transportation costs. Hazardous chemicals companies should do as much as they can to lower this part of the cost. For oil cost and lubricant cost, companies should set fuel consumption quota standards and implement rewards and punishments. Attention should also be paid to the changes in oil prices, when the oil prices are relatively cheap, storage of oil should be noticed. In addition, enterprises should reasonably plan their transport routes, reduce detour and no-load situation. Addition to the oil costs, companies should also control labour costs. Only the ones that are needed should be hired. Companies should implement the incentive system to encourage employees to improve their work efficiency. Companies should pay attention that do not blindly cut the costs for maintenance and inspection. On the one hand, these costs do not bring much pressure on companies, on the other hand, these costs directly related to the risk.

(3) Risk Control Cost Management

As mentioned before, the risk level will increases with the decrease in input. But it does not mean companies should control the costs related to risk management. Firstly, companies should know the key point of risk control very well and do not spend too much on unimportant things. Secondly, companies should purchase risk control equipment at reasonable price, using unified purchase. Thirdly, companies should check the equipment regularly and repair it in time. Regularly arrange the staff to check the equipment operation, timely maintenance, avoid the waste of maintenance. Last but not least, companies should allocation of transportation equipment management personnel, lower management costs.

5. Conclusion

The cost control of hazardous chemicals companies is very important in practice. Many experts and scholars have conducted in-depth studies on this issue. However, these studies often fail to emphasize the relationship between risk and cost inputs, neglecting that cost reduction may lead to increased risks. In this context, based on the perspective of transport chain of hazardous chemicals, the paper discusses the methods of enterprise cost control considering the risk factors. The conclusions are as follows:

(1) Hazardous chemicals company's cost input and the risks show an inverse relationship, the more the cost input, the lower the risks; the less cost input, the higher the risks. This fact tells us companies should not blindly reduce the costs associated with risk control.

(2) Hazardous chemicals companies should focus on three aspects, including storage operations cost management, transportation cost management and risk control cost management.

(3) For storage operations cost management, hazardous chemicals companies should control labour costs, make storage plans and ask for more preferential policies. For transportation cost management, hazardous chemicals companies should do as much as they can to lower this part of the cost, such as set fuel consumption quota standards, plan their transport routes and so on. For risk control cost management, hazardous chemicals companies should know the key point of risk control, purchase risk control equipment at reasonable price and check the equipment regularly and repair it in time.

Reference

Bennett G.F. 1996, Transporting hazardous waste and other materials: a guide to dot regulation, Journal of Hazardous Materials, 49(1), 103-103, DOI: 10.1016/0304-3894(96)85665-2

Bonvicini S., Leonelli P., Spadoni, G., 1998, Risk analysis of hazardous materials transportation: evaluating uncertainty by means of fuzzy logic, Journal of Hazardous Materials, 62(1), 59-74. DOI: 10.1016/s0304-3894(98)00158-7

Brockhoff L., Petersen H.J.S., Haastrup P., 1992, A consequence model for chlorine and ammonia based on a fatality index approach, Journal of Hazardous Materials, 29(3), 405-425. DOI: 10.1016/0304-3894(92)85044-2

David E., Kopac J. 2013, Aluminum recovery as a product with high added value using aluminum hazardous waste, Journal of Hazardous Materials, 261(261C), 316-324. DOI: 10.1016/j.jhazmat.2013.07.042

Erkut E., 1995, On the credibility of the conditional risk model for routing hazardous materials, Operations Research Letters, 18(1), 49-52. DOI: 10.1016/0167-6377(95)00030-n

Faghih-Roohi S., Ong Y.S., Asian S., Zhang, A.N., 2016, Dynamic conditional value-at-risk model for routing and scheduling of hazardous material transportation networks, Annals of Operations Research, 247(2), 715-734. DOI: 10.1007/s10479-015-1909-2

Fang J.S., Ford D.M., Mannan M. S., 2004, Making the business case for process safety using value-at-risk concepts, Journal of Hazardous Materials, 115(1–3), 17-26. DOI: 10.1016/j.jhazmat.2004.06.004

Guo X., Verma M., 2010, Choosing vehicle capacity to minimize risk for transporting flammable materials, Journal of Loss Prevention in the Process Industries, 23(2), 220-225. DOI: 10.1016/j.jlp.2009.07.007

Jin H., Batta R., Karwan M.H., 1996, On the analysis of two new models for transporting hazardous materials. Operations Research, 44(5), 710-723. DOI: 10.1287/opre.44.5.710

Karkazis J., Boffey T.B., 1995, Optimal location of routes for vehicles transporting hazardous materials. European Journal of Operational Research, 86(2), 201-215, DOI: 10.1016/0377-2217(94)00099-x

Larsson D.G.J., Pedro C.D., Paxeus N., 2007, Effluent from drug manufactures contains extremely high levels of pharmaceuticals, Journal of Hazardous Materials, 148(3), 751, DOI: 10.1016/j.jhazmat.2007.07.008

Leonelli P., Bonvicini S., Spadoni G., 2000, Hazardous materials transportation: a risk-analysis-based routing methodology, Journal of Hazardous Materials, 71(1-3), 283. DOI: 10.1016/s0304-3894(99)00084-9

Li P.F., Lang M.X., 2013, Hazardous materials transportation by road: fuzzy-theory-based routing design, Applied Mechanics & Materials, 397-400, 696-699. DOI: 10.4028/www.scientific.net/amm.397-400.696

Li W., 2013, Neuron network model-based control system model. Applied Mechanics & Materials, 339, 143-146. DOI: 10.4028/www.scientific.net/amm.339.143

Onishi Y., Olsen A.R., Parkhurst M.A., Whelan G., 1985, Computer-based environmental exposure and risk assessment methodology for hazardous materials, Journal of Hazardous Materials, 10(2), 389-417. DOI: 10.1016/0304-3894(85)87012-6

Plüss A., Ferrell R.E., 1991, Characterization of lead and other heavy metals in fly ash from municipal waste incinerators. Physical Review A, 8(4), 275-292, DOI: 10.1089/hwm.1991.8.275

Reniers G., Cuypers S., Pavlova Y., 2012, A game-theory based multi-plant collaboration model (mcm) for cross-plant prevention in a chemical cluster. Journal of Hazardous Materials, 209-210(1), 164, DOI: 10.1016/j.jhazmat.2012.01.004

San S.M.N., Fíguls F.J., Font S.X., Sánchez F.A., 2003, Pre-oxidation of an extremely polluted industrial wastewater by the fenton's reagent. Journal of Hazardous Materials, 101(3), 315. DOI: 10.1016/s0304-3894(03)00207-3

Sivakumar R.A., Batta R., Karwan M.H., 1993, A network-based model for transporting extremely hazardous materials, Operations Research Letters, 13(2), 85-93, DOI: 10.1016/0167-6377(93)90034-e

Torretta V., Rada E.C., Schiavon M., Viotti P., 2017, Decision support systems for assessing risks involved in transporting hazardous materials: a review. Safety Science, 92, 1-9. DOI: 10.1016/j.ssci.2016.09.008

Toumazis I., Kwon C., 2013, Routing hazardous materials on time-dependent networks using conditional value-at-risk, Transportation Research Part C Emerging Technologies, 37(3), 73-92. DOI: 10.1016/j.trc.2013.09.006

Vanderstraeten B., Lefebvre M., Berghmans J., 1996, A simple blast wave model for bursting spheres based on numerical simulation, Journal of Hazardous Materials, 46(s2–3), 145–157, DOI: 10.1016/0304-3894(95)00066-6