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FACILITY LOCATION AND ITS IMPACT ON THE ENVIRONMENT: USING A CENTRALIZED AND DECENTRALIZED APPROACH, A CASE STUDY

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ABSTRACT: *There has been an increase in consumption of goods in the last century due to the rapid economic growth all over the world. Globalization has availed large streams of goods to meet this demand but the production, transportation, storage and consumption of these goods have caused environmental problems to emerge. Manufacturing companies are facing numerous pressures from the government and consumers to produce environmentally sustainable goods. The decision to set-up a plant is a strategic issue as the best facility location does not only ensure that the costs are minimized but also take care of the impacts on the environment. This paper presents a case of ABC Chinese steel manufacturing company operating in a centralized facility location approach and intends to evaluate the impact of a decentralized approach on the environment. A simulation of the two networks is run and the results reveal that the centralized approach is more suitable for this company as it is not only economical to them but it is also environmentally sustainable due to the lower carbon emissions produced by this model. The research concludes that facility location decisions greatly impacts the environment but the approach to adopt depends on the type of the product, mode of transportation and the choices of fuel.*

KEYWORDS: facility location, environment, simulation, supply chain management, facility design

INTRODUCTION

Olugu, Wong, & Shaharoun (2011) introduces that the environmental degradation's current state and trend continues to enquire on the performance of business activities. This is as a result of the global ecosystem which is experiencing severe challenges as energy depletion and capabilities to dispose-off waste approach its limits. The economic growth of the world has risen and this has led to an increase in consumption of goods. Globalization on the other hand has availed the flow of these goods to meet the demand. Huge environmental issues have however been created by manufacturing, transporting, storing and consuming these goods. Governments, action groups and companies are becoming concerned about global warming which is caused by large scale emissions of greenhouse gases.

Treitl & Jammernegg (2014) argues that the main driver of integrating environmental sustainability in business operation is the increased regulations by the government and the growing concern by customers on going green. This means that companies have to take these factors into consideration when they are making strategic decisions such as facility location decisions to

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remain competitive. Abdul-Rashid, Sakundarini, Ghazilla, & Thurasamy (2017) maintains that manufacturing industries should make decisions that aims at enhancing environmental sustainability and this include reducing the CO_2 emissions since these emissions have negative effects to the environment. They cause global warming, changes the patterns of the weather; pollute air and forms acidic rain. These effects affect the health of people and causes imbalances of the ecosystem (International Energy Agency, 2009).

Manufacturing companies are simultaneously pushed to make the best facility location strategies in order to minimize costs. Trade-offs of costs has been fairly established; a move towards a centralized approach will reduce capital costs while one towards a decentralized approach will minimize transportation costs (Clarke-Sather, 2009) and the impact of these strategies on the environment have been considered by both researchers and practitioners in the last decade which turns the facility location optimization problem of focusing on costs alone into a multi-objective optimization problem which integrates the environment dimension when making facility decisions (Nguyen & Olapiriyakul, 2016). This paper will investigate the impact of facility location decision on the environment, using a centralized and decentralized approach, for ABC Chinese Steel Manufacturing Company.

Case Study Description

ABC is a Chinese Steel Manufacturing company employing a centralized facility decision approach where steel is shipped directly from the main warehouse located in Lai Wu city to other 33 cities in China. The centralized approach has helped this company control the high value of product. Due to the large distance between the centralized warehouse and some of the cities, the company wishes to adopt a decentralized approach. This will however depend on the cost efficiency and the impact to the environment due to the heavy environmental regulations of the government on manufacturing companies.
The Centralized Approach is as shown in the Table 1 below

Table 1: ABC Chinese Steel Manufacturing Centralized Approach

Province	City	Demand(tons/month)
An Hui	He Fei	400
	Ma Anshan	278
Fu Jian	Fu Zhou	100
	Pu Tian	97
Quang Dong	Zhong Shan	113
	Mao Ming	150
Hai Nan	Hai Kou	15
He Bei	Bao Ding	112
	Beijing	44
He Nan	Nan Yang	87
Hu Bei	Wu Han	58
Hu Nan	Chang Sha	5

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Jiang Su	Xu Zhou	1761
	Chang Shu	800
	Su Zhou	1000
	Nan Jing	2000
	Lian Yun Gang	2000
	Nan Tong	2200
Jiang Xi	Jiu Jiang	88
Liao Ning	Shen Yang	55
Shan Dong	Ji Nan	2100
	Tai An	3084
	Lin Yi	1000
	Qing Dao	1200
	Zi Bo	800
	Zao Zhuang	2200
	De Zhou	1800
Shan Xi	Tai Yuan	96
Shang Hai		3
Tianjin		72
Zhe Jiang	Hang Zhou	900
	Tai Zhou	600
	Wen Zhou	1502

LITERATURE REVIEW

Supply Chain Network Design and Environmental Impact

Nasiri & Jolai (2018) introduces that Supply Chain Network Design (SCND) is a key decision area of Supply Chain Management (SCM) that determines the numbers, location and capacities of facilities in the SC network and controls the total flow of materials between them. Pishvaee & Razmi (2012) expounds that SCND is a strategic issue in SCM as it helps a SC in evaluating its general economic and environmental performance. Forrest (2017) states that SCND aims at delivering services to customers at reduced costs, determines the optimal sourcing and inventory management techniques and optimal utilization of transportation facilities through routing. This paper aims to divide the SCND activities into facility location decisions, transportation and inventory management and evaluate their impact of the environment.

Facility Location Decisions

This involves deciding the best location for the plant, warehouses and distribution patterns. It is dependent on many factors such as the capacity of the facilities, customers demand, and government regulations among others. Wang, Lai, & Shi (2011) designed a multi-objective optimization model that aimed at solving environmental problems in terms of CO_2 emitted by production and distribution services across the Supply Chain (SC). Their numerical experiment provides a trade-off between costs and influences on the environment and delivers strategic planning insights for green SCs. Harris, Naim, Palmer, Potter, & Mumford (2011) developed a simulation model that aimed at studying how the number of depots and various ratios (90%, 75% & 60%) on utilization of freight vehicles impact on logistics costs and CO_2 emissions. Their analysis revealed the need to solve economic and environmental goals clearly as part of the design of logistics as costs based on optimal design doesn't necessarily lead to optimal CO_2 emissions solutions.

Interestingly, Ramudhin, Chaabane, & Paquet (2010) were among the first to recommend a carbon market sensitive model for strategic planning that could be used to achieve sustainability of SC networks. They employed a multi-objective MIP technique to assess the trade-offs between offsetting carbon under various SC operation strategies and overall logistics costs under constraints of environmental regulations and evolution of carbon markets. An extension to this work was done by Chaabane, Ramudhin, & Paquet (2012) who developed a MIP framework that assessed the life-cycle principles and differentiate between the various forms of wastes and emissions produced by manufacturing and transportation processes. This model aimed at creating a sustainable SC design network.

Transportation

A literature by Dekker, Bloemhof, & Mallidis (2012) reveals that while making considerations to the environment, transportation forms are the most observable characteristic of the SC as the amount of CO_2 emitted through transportation add up to 14% at EU and global levels. They maintains that operations research models support choice of mode, intermodal transportation, and choice of fuel. Hayakawa, Tanaka, & Ueki (2013) believe that the choice of transport mode is influenced by the characteristics of the product and the distance to be travelled. For instance, bulky goods like coal are transported by rail, sea while goods that are sensitive of time are transported by air. For intercontinental SCs, air and sea are mainly used while truck, air or train are highly preferred for continental SCs.

Shen, Sakata, & Hashimoto (2009) found out that the modes of transport choices are determined by the change in natural environment and improvement of transport networks. Leal & D'Agosto (2011) after exploring the best transport alternatives for exporting bio-ethanol from Brazil with financial and environmental considerations concluded that road transport was the best choice used to feed pipelines which would directly deliver ethanol to the ports. Moreover, Dekker, Bloemhof, & Mallidis (2012) enlighten that the transport unit in the same load is inversely propotional to the CO_2 emissions per g/t/km. Likewise; water transport is the most CO_2 efficient followed by rail, then trucks and lastly air.

An empirical study by Garcia, et al. (2013) developed a hybrid model that could be used for intermodal transport and they concluded that there exist a trade-off of planning time and the quality of the intermodal transport chosen. Modern gasoline that is mixed up with biofuels to raise the quality of air is cleaner. Xu, Berck, Qin, Zheng, & Wang (2014) in their study on modal choice in Beijing found out that by increasing the price of gasoline moderately, the volume of cars on transit will go down by 7% which translates to CO_2 emissions reductions by more than 700,000 tons. Additionally, Rui, Guangyi, Zongyi, Yulong, & Weijian (2007) after carrying out a life cycle analysis on natural gas alternative fuel vehicles found that fuel and vehicle production, and vehicle operation and infrastructure are important considerations to make based on the energy and environmental objectives in place.

Dekker, Bloemhof, & Mallidis (2012) highlight that electric vehicles are friendly to the environment because no emissions are produced by their engines. A review by Achtnicht, Buhler, & Hermeling (2012) however dictate that biofuel and electric cars remains to be unpopular amongst buyers despite the expansion of the infrastructure of fuelling stations. Zhang, Gensler, & Garcia (2011) investigated the issues that speed up alternative fuel vehicles (AFVs) using agent-based modelling (ABM) and they discovered that when the government dictates on manufacturers in terms of fuel economy guidelines to be met, the social good declines in terms of air pollution as there's a rise in fuel-inefficient vehicles in the market.

Inventory Management

This is a less visible aspect as compared to transportation but Chopra & Meindi (2016) consider a more comprehensive view of the different products and their different levels of their impact on the environment based on their production mode measured by their carbon footprint, their way of transportation awaiting usage (inventories), their recoverable value after use and their packaging. This is the consideration that makes some products 'greener' than others. Fichtinger, Ries, Grosse, & Baker (2015) built an integrated simulation model to examine the relationship between inventory and warehousing management and its impact on the environment and they found out that supply lead time decisions, reorder quantities and storage equipment have an effect on costs and leads to emissions on the environment.

Interestingly, there's a part of environmental impact of inventory management literature that focus on carbon emissions being converted into a monetary cost which could be a carbon tax, which is then integrated as a function of the objective. This is evidenced by Bonney & Jaber, (2011) who included the environmental cost in an EOQ model and this extension showed that more lot sizes are needed during ordering than those of the classical EOQ model that doesn't include the cost on the environment. Additionally, Hua, Cheng, & Wang (2011) finds out how organizations under the trading mechanism of carbon emissions are able to handle carbon footprints when managing their inventories by deriving an optimal ordering quantity that numerically examine how ordering decisions are impacted by carbon trade, price and cap.

METHODOLOGY

The case was analyzed using a simulation based framework where the details of the centralized and decentralized approaches were presented. According to Yin (2017) a case study research helps in identifying and describing crucial variables, highlighting any links between them, testing theories and forecasting future outcomes. The analysis of ordering patterns, transport and inventory costs and the carbon emissions were analyzed by Supply Chain Guru (SCG) software. The decentralized approach involved identifying the most suitable location of the distribution centers based on demand, capacity and transportation distance between them and the retailers as shown in Table 2 below.

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The models estimated different re-order levels and re-order quantities based on the demand and lead time patterns. Dekker, Bloemhof, & Mallidis (2012) assert that Operations Research (OR) techniques are associated with minimization of costs and this have a substantial impact on the environment. In the society of today, profits are not the only concern for customers and organizations; they're worried about environmental sustainability too and thus companies should employ OR techniques such as simulation before making facility location decisions to evaluate the feasibility of their choices. Therefore this paper adopted SCG simulation software to evaluate the costs and carbon emission as a performance metric on the environment assessment.

Table 2: The Proposed Decentralized Approach for ABC Steel Company

Distribution Centre	**City**	**Demand (tons/month)**
DC1 Nanjing	Xu Zhou	1761
	Nan Jing	2000
	He Fei	400
	Ma Anshan	278
	Chang Shu	800
	Su Zhou	1000
	Lian Yun Gang	2000
	Nan Tong	2200
	Shanghai	3
	Mao Ming	150
	Wen Zhou	1502
	Hang Zhou	900
	Tai Zhou	600
	Chang Sha	5
	Wu Han	58
DC2_Baoding	Beijing	44
	Baoding	112
	Shen Yang	55
	Tai Yuan	96
	Tian Jin	72
	Jiu Jiang	88
	Hai Kou	15
	Zhong Shan	113
DC3_Tai An	Qing Dao	1200
	Zi Bo	800
	Zao Zhuang	2200
	De Zhou	1800
	Nan Yang	87
	Ji Nan	2100
	Lin Yi	1000

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RESULTS AND DISCUSSIONS

The centralization approach calls for the use of continuous review inventory policy to solve the inventory management problem of deciding the time and quantity to replenish as inventory is reviewed repeatedly such that when inventory falls to a reordering point (R), an order of amount (Q) is placed for stock while taking lead time into account. The reorder level of the central DC in Lai Wu was determined by the sum of the demand of all the cities which was 26720 and the re-order quantities was assumed to be 80160 which was arrived from multiplying the reorder level by three. The reason for taking three is that it was the optimal figure that gave a minimal average stock and at the same time it ensured that there was no stock out.

The company uses trucks to transport steel to its customers and the total number of trucks to be used was determined by the capacity of the truck and the total number of items to be shipped which would be dependent upon demand. The trucks used were UK heavy goods which are articulated and carry a maximum of 33 tonnes. An LTL transportation policy was selected and a CO_2 basis was calculated based on the quantity and distance which was provided by Google maps in kilometres. The time taken to ship the products was also provided. SCG automatically calculated the carbon footprint of the network based on the fuel type and the type of truck used and the speed assigned which was estimated to be 55km/hr. A simulation was run for this network and the transportation cost for the network amounted to $10,540,036 while the inventory carrying cost was $109,435. The total carbon footprint summed up to over 3.3 million tonnes a month which amounts to approximately 42 million tonnes per year. Additionally, the company generated over $200 million profits and revenues annually. When a simulation was run using US EPA road trucks which would use low sulphur diesel as compared to the earlier UK Defra heavy articulated trucks, this resulted to an increase of carbon footprint by 440269 tonnes.

For the decentralized decision approach the steel is shipped directly from the main warehouse located in Lai Wu city to the three DCs which then ship the steel to their respective retailers. There are various reasons as to why companies may choose to decentralize their facilities operations. If they intend to achieve a higher service level, they'd opt for this approach. Similarly, decentralized distribution centres are characterized by low risk levels as compared to the centralized facilities and in case of a fire or any hazard only one of the DCs is affected. This approach however has higher operating costs and lower product prices which denies the company an economy of scale. The proposed model employed a LTL transportation policy and trucks were used to transport commercial steel from the warehouse to the DCs and from the DCs to the retailers. The number of trucks used was got from the warehouse and DCs demand divided by the truck capacity. Like the previous model, UK Defra Heavy Goods Articulated trucks were used and giving a consideration to the distance travelled, fuel choice, fuel surcharge, and transportation speed, a simulation was run which provided details on the total costs incurred and the carbon emitted by the network.

The transportation cost for the proposed network amounted to $12,332,644 while the inventory carrying cost was $202,455. The total carbon footprint summed up to over 3.8 million tonnes a month which amount to approximately 47 million tonnes per year. Additionally, the company would generate over $100 million profits and revenues. Changing the inventory policy to (s, S)

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had no impact on the carbon emitted. This approach however has higher operating costs and lower product prices which denies the company economies of scale. The inventory policy in this scenario was also (R, Q). Demand from the retailers was consolidated in the DCs and this allows merging of shipments. The proposed decentralized model would lead to an increased monthly cost of $1,885,628 for running the network. What is more, both transportation and inventory carrying costs would rise by $1,792,608 and $93,020 respectively. The profits of the company would drop by $70,256,368 and the monthly carbon foot print produced by this network would rise by 566,443 tonnes leading to an increased annual carbon emission of over 6 million tonnes.

CONCLUSIONS AND IMPLICATIONS

Based on the case study of the Chinese steel manufacturing company, it's clear that facility location decisions made by a company greatly impact the environment. The simulation results indicate that for this case, a centralization policy is more suitable for the company as compared to a decentralization policy. This was due to the impact of these approaches on the environment. The research reveals that the choice of fuel has an impact on the carbon emitted as the results in the previous chapter illustrate the use of low sulphur diesel increased the carbon footprint transported by the network.

In contrast to the theoretical literature that discusses that inventory management policies have an impact on the carbon emitted, this research did not concur to this claim as the carbon footprint for the network remained the same irrespective of choosing either (R, Q) or (s, S) inventory policy. These findings however, could be different for a manufacturing company in China producing a different product like clothing. It doesn't necessarily mean that centralization policy is more carbon effective than a decentralization policy. This could be argued that, when the products are shipped to a DC, consolidation of the shipments occurs and items are transported to the retailers who are within the regional DC. This calls for transporting of smaller units which would be done using vans instead of trucks. Vans would use less fuel and their reliability would mean incurring less transportation costs and the use of light goods vehicles would also translate to lower carbon emission and thus lower impacts of emissions to the environment.

In this case, trucks had to be used from the DCs to the retailers and could not be substituted to vans as commercial steel is very heavy and it requires use of heavy trucks or rail as the main mode of transport. This therefore increases transportation costs and raises the carbon foot print. Therefore, managers of manufacturing companies should make operational decisions based on the type of products their firms are dealing with to identify the most appropriate facility location decision that would help the company emit less carbon and lead to more sustainability. When using the SCG simulation software, most cities were not geo coded as their latitudes and longitudes readings were not shown by the software but this did not have an impact on the simulation results of the objectives under study.

A further area of research for this work is to compare the two facility location decisions but with the use of a different product and evaluate their environmental impact. More research is also required to investigate the impact of inventory management on the environment as using different inventory policies in this study did not provide any significant differences to the carbon emitted.

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