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CREATING SUSTAINABLE SUPPLY CHAINS FROM ENVIRONMENTAL PERSPECTIVE

KREIRANJE ODRŽIVIH OPSKRBNIH LANACA IZ EKOLOŠKE PERSPEKTIVE

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Abstract: *This paper explores the possibilities of creating and modeling sustainable supply chains from an environmental perspective. The purpose of this paper is to promote environmental sustainability. The research results are based on the mathematical method of dynamic programming. The main finding of this paper is that the first and more important step toward a greener or more sustainable supply chain is to optimize supply chains from the total (economic and environmental) costs.*

Keywords: *sustainability, supply chains, economic costs, environmental costs, dynamic programming*

Sažetak: *Cilj ovoga rada jest istražiti mogućnosti kreiranja i modeliranja održivih opskrbnih lanaca iz ekološke perspektive. Svrha rada jest promicanje održivosti okoliša. Rezultati istraživanja temelje se na matematičkoj metodi dinamičkog programiranja. Glavni nalaz ovoga rada upućuje na zaključak da je optimizacija opskrbnih lanaca s motrišta ukupnih (ekonomskih i ekoloških) troškova prvi i najvažniji korak prema zelenijim i održivim opskrbnim lancima.*

Ključne riječi: *održivost, opskrbni lanci, ekonomski troškovi, ekološki troškovi, dinamičko programiranje*

1. Introduction

Despite significant progress and numerous examples of good practice, the concept of sustainable development, which includes improving economic and social well-being while protecting the environment, may not have achieved the desired global sustainability. Global supply chain has a large effect on the environment. From sourcing raw materials to create products, to how finished products are transported to their final distributor, the supply chain can utilize many valuable, non-renewable resources during each step of the way. Environmental crises are distinguished by rapid and largely unexpected changes in environmental quality that are difficult if not impossible to reverse (Taylor, 2009). With the Covid-19 crises, disruption in global supply chains, inflation, war in Ukraine and energetic crises it's very hard to think about environmental crises. Business world has focused, mainly on economic sustainability.

The impact of the supply chain on the environment is primarily negative. The typical consumer company's supply chain creates far greater social and environmental costs than its own operations, accounting for more than 80 percent of greenhouse-gas emissions and more than 90 percent of the impact on air, land, water, biodiversity, and geological resources (Bové & Swartz, 2016). Consumer companies can thus reduce those costs significantly by focusing on their supply chains. Accordingly, the main hypothesis of this work is: The incorporation of environmental sustainability into supply chains is a critical step toward achieving sustainable development. The methods of analysis and synthesis, comparative method, and the dynamic programming method were used to prove the hypothesis.

2. Literature review

2.1. Supply chains

A supply chain consist of all stages involved, directly or indirectly, in fulfilling a customer request. A typical supply chain consists of: customers, retailers, wholesalers/distributors, manufactures and component/raw material suppliers. Success in the supply chain is measured in terms of supply chain profitability. The higher the supply chain profitability, the more successful the supply chain (Chopra & Meindl, 2001). For many companies, sustainability is gaining a new dimension. Sustainability has become increasingly important not just from economic but also from ecological and social perspective. While traditional supply chain management focuses on operational speed, cost, and reliability, sustainable supply chain management incorporates the goals of environmental and societal values. This includes dealing with global issues like climate change, water security, deforestation, human rights, fair labor practices, and corruption.

2.2 Sustanibility

Sustainability refers to the long-term maintence of systems according to environmental, economic and social perspecitve (Crane & Matten, 2010: 34). The incorporation of sustainability into supply chains is a critical step toward achieving sustainable development, as supply chains consider the product from the time raw materials are first processed until it is delivered to the end user.

2.2.1. Economic Sustainability

Economic sustainability, sometimes known as the “profit” pillar, is correlated with economic development, growth, productivity, profitability, and the stability of prices and markets (Elkington, 1994; Kuhlman and Farrington, 2010). This pillar in business relates to a company’s short- and long-term profitability, which may be assessed using metrics like revenues and market capitalization (Zarra, et al, 2019). Economic sustainability refers to a company’s ability to compete fairly in a given industry. It includes respect for copyright, prevention of counterfeit goods (OECD-EUIPO, 2016), and avoidance of anti-competitive practices (Yang and Ji, 2016).

2.2.2. Environmental Sustainability

Environmental sustainability, the most researched pillar of sustainability, focuses on how we use raw materials to meet human needs and the environmental damage that this causes. Environmental sustainability is the „planet“ pilar (Elkington, 1994; Kuhlman and Farrington, 2010). Environmental sustainability promotes recycling, resource reuse, and environmental damage mitigation.

2.2.3. Social Sustainability

Social sustainability has a critical importance for human life. Social sustainability lacks a broadly accepted definition (Cope, Keman, Sanders & Ward, 2022). Social responsibility can be defined as ability of local community to create a life from itself for itself. It is a „people“ pilar. Sociial sustainability is a complex concept that include topics such as (Şebnem Yılmaz Balaman): health and social equity, human rights, labor rights, practices and decent working conditions, social responsibility and justice, community development and well-being, product responsibility, community resilience, and cultural competence.

2.3. Environmental Sustainability and Supply Chains

Companies face pressure to improve *environmental sustainability* in *supply chain*. The “greening” of a supply chain is the management process by which manufacturers, buyers, and retailers reduce their environmental impact throughout the value chain. It involves all stages, including product design, material selection, manufacturing process, transportation of goods, and the recycling and disposal of used goods. Environmental goals that can "green" a company's supply chain include: 1) reducing energy, water, and natural resource consumption, 2) increasing clean and renewable energy use, 3) decreasing waste production and pollution emissions and 4) improving waste byproducts treatment.

3. Matherial and methods

Let's say (Pupavac, Krpan, Marsanić, 2021) that for a product to be manufactured and delivered on the demand location within the supply chain, certain production and logistic activities need to be done and which can be classified in five phases (I-V): x_1 (procurement of raw materials), x_2 (production), x_3 (warehousing and land transport), $x_{4,}$ (maritime transport), x_5 (distribution), and for which within the global logistic system it is possible to engage 27 different participants: f_1, f_2, f_3...,f_{23}. (cf. Table 1).

Table 1. Production phases within the supply chain and potential supply chain participants

Phases of logistic process	Potential supply chain participants	Costs of each phase within the supply chain (in 000 €)		
1	2	3		
		Economic	**Environmental**	**Total**
I. Delivery of raw materials Incoterms EXW - Ex Works	f_1– Russia	11	(35×0.03)=1.05	12.05
	f_2 – Finland	12	(25×0.03)=**0.75**	12.75
	f_3 – Egypt	14	(40×0.03)=1.20	15.20
	f_4 – Bulgaria	14	(30×0,03)=0,9	14.90
	f_5 – Moldavia	**10**	(35×0,03)=1,05	**11.05**
	f_6 – Belarus	11	(45×0,03)=1,35	12.35
II. Production	f_7 – Czech	32	(32×0.03)=0.96	32.96
	f_8 – Romania	22	(40×0.03)=1.2	23.20
	f_9 – Poland	26	(25×0.03)=**0.75**	26.75
	f_{10} – Slovakia	24	(30×0.03)=0.9	24.90
	f_{11} – Serbia	**20**	(50×0,03)=1,5	**21.50**
III. Warehousing and land carriage (railway operator, road transport operator)	f_{12} – national railway operator	**8**	(0.7×0.03)=**0.021**	**8.021**
	f_{13} – ABC Logistics	9	(4.5×0.03)=0.135	9.135
IV. Sea shipping (ship operators)	f_{14} - Global Alliance	**7**	(31.2×0.03)=0.936	**7.936**
	f_{15} - Grand Alliance	8	(30.0×0.03)=**0.9**	8.90
	f_{16} - Maersk-Sealand	10	(33.0×0.03)=0.99	10.99
V. Distribution (distributors in North America)	f_{17} – East Coast	12	(2.8×0.03)=**0.084**	12.084
	f_{18} – West Coast	**11**	(3.1×0.03)=0.093	**11.093**
	f_{19} – Canada	14	(3.5×0.03)=0.105	14.105
I., II.	f_{20} – Austria	30	(65×0.03)=1.95	31.95
II., III.	f_{21} – Switzerland	36	(40×0.03)=1,2	37.20
I., II., III.	F_{22} – GB	42	(75×0.03)=2.25	44.25
II., III., IV.	F_{23} – Croatia	40	(60×0.03)=1.8	41.80
III., IV., V.	f_{24} – Germany	28	(28×0.03)=0.84	28.84
III., IV.	f_{25} – Italy	22	(30×0.03)=0.9	22.90
IV., V	f_{26} – USA	20	(25×0.03)=0.75	20.75
	f_{27} – USA	**18**	(22×0.03)=**0.66**	**18.66**

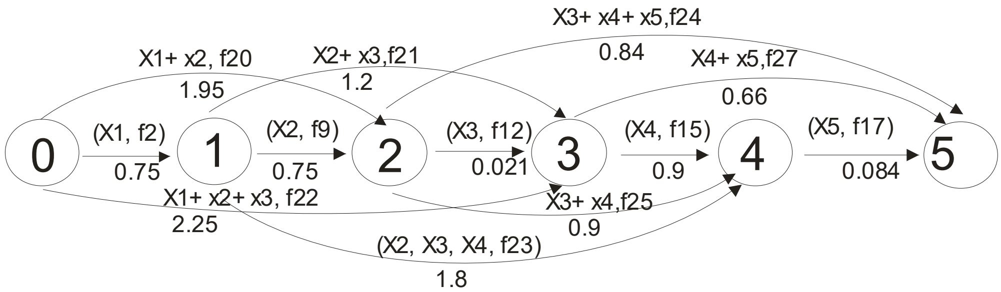
The assumption is that the supply chain produces and delivers 100 tons of goods per month. Economic and environmental costs are arbitrarily estimated. Economic costs are the cost price of each stage within the supply chain. Environmental costs refer to pollution of rivers, air, environment, waste, and are expressed in monetary units in such a way that their cost is estimated at 30 EUR/t CO_2. The ecological costs of transport were estimated in such a way that the CO_2 emission of truck transport is 150 g-CO_2/tkm, sea transport 39 g-CO_2/tkm and rail transport 20 g-CO_2/tkm (Niwa, 2009).

4. Results and discussion

Based on the data from table 1, it is evident that in order to design an optimal network from an economic, environmental or total cost aspect, it is not necessary to consider all potential participants, but only some of them. Once non-competitive potential supply chain participants have been eliminated, it is possible to approach the design of the appropriate supply chain network and solve the problem posed.

The following shows the supply chain network from a environmental aspect (cf. figure 1).

Figure 1. Logistic network of potential qualified global supply chain participants from environmental aspect



Above every branch of the logistic network (cf. *Figure 1*) a logistic chain phase is entered as well as potential participants for carrying out a certain activity within the global logistic chain and under the branches of the logistic network costs for carrying out a certain phase within the logistic chain are entered.

In the following, the problem of the shortest path in the network is solved from an environmental aspect by applying the dynamic programming method. Other problems (from economic and total costs aspects) were solved according to the same principle, and the description of their solution is omitted. By applying the recursive expression the following is obtained

f(0) = 0 i f(1) = 0.75, and then

$$f(2) = \min \begin{cases} f(0) + c(x1 + x2, f20 = 0 + 1.95 \\ f(1) + c(x2, f9 = 0.75 + 0.75 \end{cases} \}=1.50$$

$$f(3) = \min \begin{cases} f(0) + c(x1 + x2 + x3, f22 = 0 + 2.25 \\ f(1) + c(x2 + x3, f21 = 0.75 + 1.2 \\ f(2) + c(x3, f12) = 1.5 + 0.021 \end{cases} \} = 1.521$$

$$f(4) = \min \begin{cases} f(0) + \infty = 0 + \infty = \infty \\ f(1) + c(x2 + x3 + x4, f23) = 0.75 + 1.80 \\ f(2) + c(x3 + x4, f25) = 1.50 + 0.90 \\ f(3) + c(x4, f15) = 1.521 + 0.90 \end{cases} \}=2.40$$

and finally

$$f(5) = \min \begin{cases} f(0) + \infty = 0 + \infty = \infty \\ f(1) + \infty = 10 + \infty = \infty \\ f(2) + c(x3 + x4 + x5, f24 = 1.5 + 0.84\} = 2.181 \\ f(3) + c(x4 + x5, f27) = 1.521 + 0.66 \\ f(4) + c(x5, f17) = 2.40 + 0.084 \end{cases}$$

which means that the length of the shortest path is p*, i.e. the minimum value of the function of the target z* = d(p*) = 2.181, and in this example we have optimum ways p* = (0,1,2,3,5). If the managers choose this solution they will have a cost of supply chain from 66 810 €. The optimal supply chain formed from an economic aspect will have a cost in the amount of 56,000€. We can conclude that a supply chain which is optimized from a environmental aspect has a higher cost for 22,87 % than a supply chain which is optimized from an economic aspect. An overview of other optimal solutions from different aspects is given in table 2.

Table 2. Overview of optimal solutions

Optimization by aspects	Optimal way on network	Supply chain participants	Economic costs (000 €)	Environmental costs (000 €)	Min total costs (000 €)
Economic	0,1,2,3,4,5	f5,f11,f12,f14,f18	56	4.497	60.497
	0,2,3,4,5	f20,f12,f14,f18	56	3.000	59.000
	0,2,3,5	f20,f12,27	56	2.631	58.631
Environmental	0,1,3,5	f2,f9,f12,f27	64	2.181	66.810
Total costs	0,2,3,4,5	f20,f12,f14,f18	56	3.000	59.000

Based on the data from table 2, we can see that we have not optimal solutions which do not include environmental costs. The optimal solution from the environmental aspect is higher 13.95 % than the best solution from the economic aspect which includes potential environmental cost. It seems reasonable to choose the best solution from the total costs aspect which is also one of the three optimal solutions from the economic aspect. This solution will have slightly higher environmental costs than in the optimal solution, but it is a sure way towards their reduction and elimination.

5. Conclusion

A growing number of multinational firms have made the commitment in recent years to only do business with suppliers who uphold social and environmental criteria. The most problem arises at first-tier suppliers. Lower-tier suppliers nearly always have worse business practices, which exposes businesses to more substantial financial, social, and environmental risk. The findings of this scientific discussion confirmed the possibility of developing more optimal supply chains in terms of environmental costs. The difference in economic (total) costs in the resulting supply chains is negligible. Optimizing supply chains from the standpoint of economic costs yields significantly better results only if potential environomenat costs are ignored. Supply chain managers must set goals that intentionally create productive tension between economic and environmental criteria and move the supply chains toward a sustainable future.

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