Application of Game Theory in Multimodal Transport Operator Processes

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Abstract
This paper presents an application of game theory in supply chain management, and more specifically the relationship between the multimodal transport operator (MTO) and the various parties that mediate in order the goods to reach their destination. Game theory has been established in a variety of sectors and disciplines, one of which is the supply chain management as a field of the science of management, since the decision making is of particular importance and significance. In this context, the role of game theory in the management of the multimodal transport of goods (i.e. transport of goods by at least two different means of transport but under a single contract), a sector developed as imperative need of the rapid growth and the globalization of markets, seems to be special. Thus, this study presents an application of game theory in the problem of the multimodal transport operator, according to which perishable edible commodities must be transported from Greece to China, given that there are short time limits and relevant sanctions, and aims to identify the best strategy by solving this game.

Keywords: Game theory, Supply Chain Management, Multimodal Transport, Multimodal Transport Operator (MTO)

Introduction

Game Theory is a mathematical method that provides the necessary mathematical models and techniques, through which the strategic interactions between the individual entities involved are represented and analyzed, which are required to make various decisions (Myerson, 1997; Carmichael, 2005; McCain, 2010). The main aim of these entities is to serve their own interests, and maximize the benefits accruing (Luce and Raiffa, 1957), while the ultimate goal of game theory is to predict the outcome of these interaction strategies.

The basic assumption of game theory is the rationalism which characterizes the entities interacting. More specifically, the interaction of these entities supposedly takes place in a social structure in which they are allowed to act autonomously, while at the same time they act strategically with rationality and self-interest with a view to maximize their potential earnings (Myerson, 1997; Burns and Roszkowska, 2005). Another key element of game theory is the Nash equilibrium, which describes a situation in which «each player's strategy is optimal against those of the others» (Nash, 1951).

Therefore, in the context of game theory the interactions between the game players (ie the parties involved) are defined and formed, and then all the possible results, or else all the possible solutions of the game under which each strategy is planned for each player in order to achieve the desired results, are identified.

It is noteworthy that, game theory first appeared in the 1940s by John von Neumann and Oskar Morgenstern as a mathematical method, and then it was developed so as to find application in a variety of disciplines, among which the social and the economic science are included.

Consequently, many researchers have got involved in the application of game theory and supply chain management, an especially important area for every business since it gives to the business competitive advantage (Li et al., 2006). As a concept, the supply chain can be defined as the set of entities (organizations or individuals), information, activities and resources that contribute to a product or service to reach the customer supplier (Mentzer et al., 2001) while the supply chain management according to Cooper et al. (1997) is defined as «an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user».

The importance of the supply chain management arises from the rapid growth of international competition, the continuous development of technology that leads to shorter production processes, the growing need for cost reduction, and the lifetime and the safety of the products. Therefore, an efficient supply chain management meets all the resulting requirements. Incidentally, the critical point is the identification and design of efficient supply chain management, in which the game theory can play a catalytic role.

Regarding the application of the game theory in the supply chain there is a number of studies in the international literature. For example, Nagarajan and Sosic (2006) studied a number of game theory applications in supply chain management, focusing on the distribution of costs and the stability. Moreover, Hannet and Arda (2008) developed a model that combines the queuing theory and the game theory to assess the effectiveness of different contracts between partners in the supply chain. Furthermore, Jalali Naini et al. (2011) applied the game theory in the supply chain of an auto industry in Iran, while the Zamarripa et al. (2012) studied the supply chain design in a competitive environment using cooperative and non-cooperative games.

Certainly, due to the globalization of markets, within the supply chain it is almost impossible to carry out the transfer of a product with only one means of transport to any part of the world while satisfying all the requirements as mentioned above. Thus, the need to integrate the various means of transport in a single transport system (Lingaitiene, 2008) was created. This is precisely the object of Multimodal Transport, which specifically refers to cargoes by two or more means of transport and their management under a contract and a transport document (UN, 1980). The operator of such transfers is called Multimodal Transport Operator, and he is the person who enters the contract of multimodal transport and is responsible for the execution of the contract. Still, he does not act as an agent. Thus, the MTO should select and combine both the transport and the storage installations of loads that may be used in the most efficient way from the receiving point to the delivery point and in accordance with the customer requirements.

From the above, it is conceivable that the advantages of the multimodal transport include the reduction of the delivery time, the increase of the accuracy in delivery time and the reduction of the distribution costs, which bring a significant competitive advantage for the suppliers who choose this mode of transport for their goods (SteadieSeifi et al., 2014; Harris et al., 2015). Furthermore, it should not be omitted that through multimodal transport even small businesses can develop their distribution network and gain access to the international trade.

Despite the special importance of the multimodal transport, research and studies in this field are limited. Using mathematical models and algorithms, these investigations focus either on the planning and coordination of the combined transport, or on the selection of the optimal route, always aiming to maximize the quality of the transport and reduce costs (Oduwole, 1995; Banomyong and Beresford, 2001; Schonharting et al., 2003; Russ et al., 2005; Yamada et al., 2009; Hu, 2011).

From all the above, it is concluded that the multimodal transport is an area ideal for the application of game theory, since through it useful results could be yielded, taking into account all the possible actions of the parties involved and resulting in the optimal solution. Thus, this study aims to apply game theory in the MTO problem by presenting a case study in which the MTO undertakes to transfer a load from Greece to China using road and sea transport. Through the analysis of this problem, with the help of game theory, all the possible cases concerning time and freight cost are provided, and eventually the case with the greatest benefit for the MTO is identified.

Methodological Framework

As it has become clear, the MTO problem is to be analyzed and solved with the help of game theory. In particular, it has been considered appropriate to develop five two-player games, each of which represents the phase in which every time the load is transported. In each game the MTO engages directly as the one which coordinates the entire transporting, interacting with each involved party. Therefore, it is understood that in each game player 1 refers to MTO and player 2 refers to each party involved, i.e. the carrier that each time performs the transportation of the load until it reaches its final destination. In addition, each player has at their disposal a finite number of options, listed as strategies. By extension, for each combination of strategies, there are specific payoffs, which, as it will be discussed in the next section, depend on the time of receipt and delivery of the load, as well as on the related penalties, discounts, and storage and management costs that may arise. It is noted that, the games are developed in a strategic form, using a table which correlates the players' strategies with their returns. Furthermore, it is worth mentioning that for the analysis and resolution of the games the GameView software was used.

Based on the above, for the analysis and resolution of each game the following steps were followed. Initially, after identifying the rewards, the table game results were developed. Then, the dominant strategies were identified and the exact percentages of the rewards for every possible strategy for each player were exported. Thereafter, with the help of diagrams, it was examined whether the dominant strategies identified are weak or strict. Finally, in order to solve each game the Nash equilibrium and the optimal strategy for each game were identified.

The MTO Game

The main problem to be faced by an MTO is the accuracy in time and proper planning of the various successive types of transport in order to perform the work in an optimal way and achieve the maximum profit. The importance of accuracy in the planning and execution of the MTO operations emerges through the game, which is developed below.

Initially, the MTO game to be tested refers to sending a fruit load from a producer of Katerini in Greece, to a customer-fruit merchant in China, particularly in the city of Ningbo. At this point, it is worth noting that the fruits are perishable products, and hence the accuracy at the time of shipping plays a crucial role for the proper execution of the order. For this reason, the MTO project is quite difficult as it involves the synchronization of all the involved parties so that the load to reach the final destination in good condition. The MTO therefore takes the receipt of the load from the producer in Katerini, the organization and assignment of transmission to the respective transporters at intermediate stops and the final delivery to the customer in Ningbo of China. In this MTO game, a total of six players participate, one of which is the MTO, who interacts with the other five players. These players represent the transporter in the successive stops from the receipt of the load until the final delivery. Additionally, it is noted that there are specific penalties in the contracts in case of late arrival, which lead to payment cuts. To understand the work of the MTO, and the games to be tested, the process followed by the receipt of load until the delivery is briefly shown.

First of all, the MTO (player 1 for all games of MTO problem) receives a load of fruit from the producer in Katerini (player 2 for the first game of the MTO problem). The load from Katerini should be transferred to the port of Thessaloniki. The transfer from Katerini to Thessaloniki's port undertakes a transport company A (player 2 for the second game of the MTO problem). Then, the load must be transported from the port of Thessaloniki to the port of Ningbo (player 2 for the third game of the MTO problem) in China. After the required customs inspection at the port of Ningbo, (player 2 for the fourth game of the MTO problem), the fruit load is received by a transport company B (Player 2 in the fifth game of the MTO problem), which undertakes the transport and delivery to the customer-fruit merchant in the city of Ningbo.

Regarding the above games that will be analyzed subsequently, whether the dominant strategies are weak or strict and also they are resolved by identifying the Nash equilibrium. Finally, specific payoffs for each game have been developed.

More specifically, in the first game, the MTO's payoffs for the delivery of goods to China, and the fruit producer's in Katerini payoffs, relating to the delivery of load from the plant, were defined. Table 1 shows the two players' payoffs, taking into account reductions in payments for late delivery. Thus, for example, if the MTO is slow to receive the goods, their delivery is also late, the MTO is paid seven utility units, while the producer is paid eight utility units. Conversely, if the MTO accepts the load earlier than the scheduled time and deliver it earlier to the fruit merchant in China both players are paid eleven utility units each.

Table 1: 1st game of the MTO problem

MTO PROBLEM		**FRUIT**		
		LATE	**ON TIME**	**EARLY**
MTO	**LATE**	7 , 8	6 , 8	6 , 8
	ON TIME	10 , 8	10 , 10	10 , 11
	EARLY	10 , 9	10 , 11	11 , 11

Then, after the table of the game developed by means of the GameView software, it is observed that both players have the same dominant strategy (early, early), on which the load is delivered earlier than the estimated time in China (Table 2). More specifically, this strategy rewards the MTO with 31 utility units and the producer from Katerini with 30 utility units.

Table 2: Dominant strategies of the 1st game of the MTO problem

7	8	6	8	6	8	Payoff p1:19
10	8	10	10	10	11	Payoff p1:30
10	9	10	11	11	11	Payoff p1:31
	Payoff p2:25		Payoff p2:29		Payoff p2:30	

In addition, Figure 1 shows the exact percentages of payoffs for every possible strategy of the MTO and the producer, which in the absence of Nash equilibrium is the only way to check the optimal strategy of each player.

Player 1:	Player 2:
Payoff p1 Strategy 1,1 : 36.84 %	Payoff p2 Strategy 1,1 : 32 %
Payoff p1 Strategy 1,2 : 31.58 %	Payoff p2 Strategy 1,2 : 32 %
Payoff p1 Strategy 1,3 : 31.58 %	Payoff p2 Strategy 1,3 : 36 %
Payoff p1 Strategy 2,1 : 33.33 %	Payoff p2 Strategy 2,1 : 27.59 %
Payoff p1 Strategy 2,2 : 33.33 %	Payoff p2 Strategy 2,2 : 34.48 %
Payoff p1 Strategy 2,3 : 33.33 %	Payoff p2 Strategy 2,3 : 37.93 %
Payoff p1 Strategy 3,1 : 32.26 %	Payoff p2 Strategy 3,1 : 26.67 %
Payoff p1 Strategy 3,2 : 32.26 %	Payoff p2 Strategy 3,2 : 36.67 %
Payoff p1 Strategy 3,3 : 35.48 %	Payoff p2 Strategy 3,3 : 36.67 %
Payoff strategy 1 : 23.75 %	Payoff strategy 1 : 29.76 %
Payoff strategy 2 : 37.5 %	Payoff strategy 2 : 34.52 %
Payoff strategy 3 : 38.75 %	Payoff strategy 3 : 35.71 %
Highest Payoff stategy:31	Highest Payoff stategy:30
Lowest Payoff stategy:19	Lowest Payoff stategy:25

Figure 1: Percentage of payoffs for the strategies of the 1st game of the MTO problem

After that, in order to determine whether the dominant strategies are strict or weak, through the GameView software Chart 1 and Chart 2 were exported, for the player 1 and player 2 respectively. The analysis of the two line chart take account of the general rule that when the lines are tangent or intersect, dominance is weak, and when the lines are separated and not touching, dominance is strict. Thus, for the dominant strategies of the game it is concluded that the third strategy (early) for both player 1 and player 2 is weakly dominant in the other two, since the lines are tangent. It is then understood that once the MTO has interest and therefore wishes to receive the load from the producer earlier than the predetermined time, and on the other producer's interest and therefore wishes to deliver the load to China merchant earlier the predetermined time.

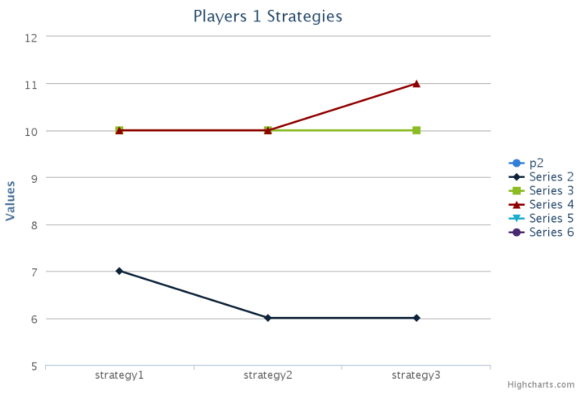

Chart 1: Line chart of player 1's strategies for the 1st game of the MTO problem

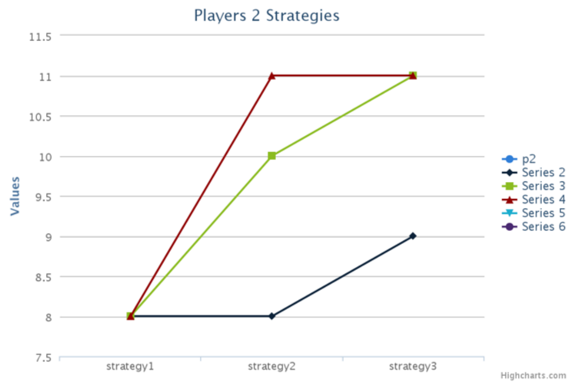

Chart 2: Line chart of player 2's strategies for the 1st game of the MTO problem

Finally, regarding the resolution of the 1st game of the MTO problem, as shown in Table 3, two Nash equilibria are identified. The first Nash equilibrium refers to the case that the MTO receives the load earlier than the predetermined time, but it is delivered to the fruit merchant of China at the predetermined time, and the second Nash equilibrium refers to the case that the MTO receives the load earlier than the predetermined time, and it is delivered to the merchant from China earlier than the predetermined time. It is observed that both equilibriums are on the third strategy (early) of MTO, while for the producer they are shared in the second strategy (on time) and the third strategy (early). It is realized that for the first player, i.e., the MTO, it is very important to receive the fruit load before the predetermined time while for the producer it is important to deliver the fruit load earlier than the predetermined time. Thus, a plus utility unit derives in connection with the delivery of the cargo at the predetermined time (eleven utility units over ten utility units). Moreover, it is worth noting that the second Nash equilibrium is Pareto-optimal since both players benefit eleven utility units respectively, and no one wants a different result.

Table 3: Nash equilibrium of the 1st game of the MTO problem

7	8	6	8	6	8	
10	8	10	10	10	11	
10	9	10	11	11	11	

Concerning the second game, the MTO payoffs were defined regarding the payment of the transport company for the transporting of the load. Also, the transport company A payoffs were defined, relating to the transfer of load from the fruit producer from Katerini to Thessaloniki port. Table 4 shows the two players' payoffs, taking into account reductions in payments for late delivery. So for example if the transport company A is late in delivering the load, resulting in delaying the MTO in its schedule, both players are paid seven utility units each. Conversely, if the transport company A receives the load earlier than the scheduled date and delivers it earlier to the port of Thessaloniki, both players are paid nine utility units each. At this point, it should be noted that if the fruit load is delivered to the port of Thessaloniki before the scheduled date, the transport company A, based on the signed contract, has the rent for the storage of load in the port as an extra charge.

Table 2: 2nd game of the MTO problem

MTO PROBLEM		TRANSPORTER A		
		LATE	**ON TIME**	**EARLY**
MTO	**LATE**	7 , 7	7 , 11	7 , 10
	ON TIME	7 , 5	10 , 10	9 , 9
	EARLY	7 , 4	10 , 10	9 , 9

Then, once the table in this game was developed with the help of the GameView software, it is noted that both players have dominant strategies. Also, MTO is observed to have two dominant strategies (on time and early), where the load is delivered by the producer to the transport company A in the predetermined time and earlier than the predetermined time respectively. These strategies reward MTO with 26 utility units, while, it is understood that, since they have the same utility units, the dominant strategies are weak. Moreover, transport company A is observed to have a dominant strategy (on time), during which the load is delivered to the port of Thessaloniki at the predetermined time and which rewards a transport company A with 31 utility units.

Table 5: Dominant strategies of the 2nd game of the MTO problem

7	7	7	11	7	10	Payoff p1:21
7	5	10	10	9	9	Payoff p1:26
7	4	10	10	9	9	Payoff p1:26
	Payoff p2:16		Payoff p2:31		Payoff p2:28	

In addition, Figure 2 shows the exact percentages of payoffs for every possible strategy of the MTO and the transport company A, which, as mentioned above, in the absence of Nash equilibrium is the only way to check the optimal strategy of each player.

Then, in order to determine whether the dominant strategies are strict or weak through the GameView software exported Chart 3 and Chart 4 of the player 1 and player 2 respectively. For the analysis of the two radar charts it is taking into account the general rule that when the lines are tangent or intersect, dominance is weak, and when the lines are separated and not touching, dominance is strict. Therefore, the dominant strategies of the game conclude that the second and third strategy (on time and early) for player 1 are weakly dominant in the first, while the second strategy (on time) for player 2 is strictly dominant in the other two, since the lines do not contact. It is then understood that once the MTO has interest and therefore wishes to deliver the load from the producer to the transport company A either on time or earlier than the predetermined

Player 1:	Player 2:
Payoff p1 Strategy 1,1 : 33.33 %	Payoff p2 Strategy 1,1 : 43.75 %
Payoff p1 Strategy 1,2 : 33.33 %	Payoff p2 Strategy 1,2 : 31.25 %
Payoff p1 Strategy 1,3 : 33.33 %	Payoff p2 Strategy 1,3 : 25 %
Payoff p1 Strategy 2,1 : 26.92 %	Payoff p2 Strategy 2,1 : 35.48 %
Payoff p1 Strategy 2,2 : 38.46 %	Payoff p2 Strategy 2,2 : 32.26 %
Payoff p1 Strategy 2,3 : 34.62 %	Payoff p2 Strategy 2,3 : 32.26 %
Payoff p1 Strategy 3,1 : 26.92 %	Payoff p2 Strategy 3,1 : 35.71 %
Payoff p1 Strategy 3,2 : 38.46 %	Payoff p2 Strategy 3,2 : 32.14 %
Payoff p1 Strategy 3,3 : 34.62 %	Payoff p2 Strategy 3,3 : 32.14 %
Payoff strategy 1 : 28.77 %	Payoff strategy 1 : 21.33 %
Payoff strategy 2 : 35.62 %	Payoff strategy 2 : 41.33 %
Payoff strategy 3 : 35.62 %	Payoff strategy 3 : 37.33 %
Highest Payoff stategy:26	Highest Payoff stategy:31
Lowest Payoff stategy:21	Lowest Payoff stategy:16

Figure 2: Percentages of payoffs for the strategies of the 2nd game of the MTO problem

time, and the other hand the transport company A has an interest, and therefore wants to deliver the load to the port of Thessaloniki on time in order to maximize its profit.

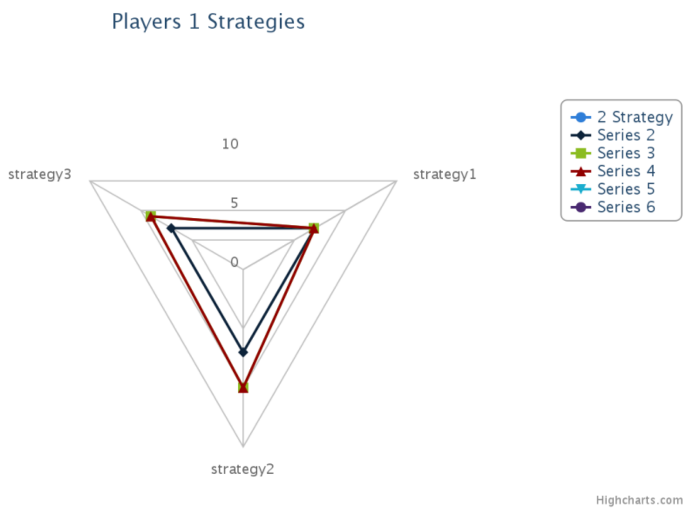

Chart 3: Radar chart of player 1 strategies for the 2nd game of the MTO problem

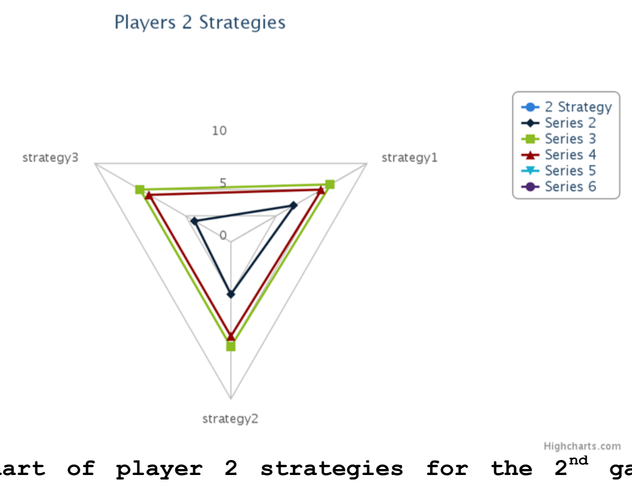

Chart 4: Radar chart of player 2 strategies for the 2nd game of the MTO problem

Finally, regarding the resolution of the second game of MTO problem, as shown in Table 6, two Nash equilibrium are identified. The first Nash equilibrium refers to the situation where the load is received and delivered to the predetermined time, and the second Nash equilibrium refers to the situation where the load is taken up earlier but is delivered in a predetermined time. It is observed that both equilibriums are on the second strategy (on time) of the transport company A, while for the MTO they are shared in the second strategy (on time) and the third strategy (early). From this, it is understood that for the first player, i.e. the MTO, it is essential to deliver the load at the port of Thessaloniki at the predetermined time or earlier than the predetermined time, and for the second player, i.e. the transport company A, it is important to receive and deliver the fruit load in the predetermined time, according to the dominant strategy.

Table 6: Nash equilibrium of the 2nd game of the MTO problem

7	7	7	11	7	10	
7	5	10	10	9	9	
7	4	10	10	9	9	

Next, the transfer of the load from the port of Thessaloniki to the port of Ningbo in China is needed to make, and for this purpose the third game of the MTO problem has been developed. In this game the MTO payoffs were defined relating to the payment of the Thessaloniki port for the transportation of goods to China, as well as the port of Thessaloniki's payoffs relating to the shipment of the load to the preset date to the port of Ningbo. For the late arrival of the load at the port of Thessaloniki is considered that the departure of the ship that will carry it to the port of Ningbo will be the time of the arrival of the load, but in this case the management cost for the port increases . The following table (Table 7) shows the two players' payoffs, taking into account reductions in payments due to late departure of the load, and discounts on payments in case of delay due to the fault port. For example, if the MTO is on time but the port is late in the shipment of goods, the MTO pays seven utility units and the port nine utility units. In another case where the load go earlier than the scheduled date, the MTO paid nine utility units due to the cost of storage charges and the port ten utility units. These extra charges in the case of load arrival at the port of Thessaloniki earlier than the predetermined time, the transport company A is paid based on the signed contract.

Table 3: 3nd game of the MTO problem

MTO PROBLEM		PORT A	
		LATE	ON TIME
MTO	LATE	7 , 10	9 , 9
	ON TIME	7 , 9	10, 10
	EARLY	6 , 9	9 , 10

Subsequently, after the table in this game was developed with the help of the GameView software (Table 8), it is observed that both players have a dominant strategy. For the MTO, a dominant strategy (on time) at which the load is delivered to the port of Thessaloniki is observed in the predetermined time, and which rewards them with seventeen utility units. Similarly, for the port of Thessaloniki a dominant strategy is observed (on time) at which the load is sent to the predetermined time, and that gives a reward of twenty-nine utility units.

Table 8: Dominant strategies of the 3rd game of the MTO problem

7	10	9	9	Payoff p1:16
7	9	10	10	Payoff p1:17
6	9	9	10	Payoff p1:15
	Payoff p2:28		Payoff p2:29	

In addition, Figure 3 shows the exact percentages of payoffs for every possible strategy of MTO and the port of Thessaloniki, as well as the smallest and the largest reward for each player.

Player 1:	Player 2:
Payoff p1 Strategy 1,1 : 43.75 %	Payoff p2 Strategy 1,1 : 35.71 %
Payoff p1 Strategy 1,2 : 56.25 %	Payoff p2 Strategy 1,2 : 32.14 %
Payoff p1 Strategy 2,1 : 41.18 %	Payoff p2 Strategy 1,3 : 32.14 %
Payoff p1 Strategy 2,2 : 58.82 %	Payoff p2 Strategy 2,1 : 31.03 %
Payoff p1 Strategy 3,1 : 40 %	Payoff p2 Strategy 2,2 : 34.48 %
Payoff p1 Strategy 3,2 : 60 %	Payoff p2 Strategy 2,3 : 34.48 %
Payoff strategy 1 : 33.33 %	Payoff strategy 1 : 49.12 %
Payoff strategy 2 : 35.42 %	Payoff strategy 2 : 50.88 %
Payoff strategy 3 : 31.25 %	Payoff strategy 3 : NaN %
Highest Payoff stategy:17	Highest Payoff stategy:29
Lowest Payoff stategy:15	Lowest Payoff stategy:28

Figure 3: Percentage of payoffs for the strategies of the 3rd game of MTO problem

Furthermore, in order to determine whether the dominant strategies are strict or weak through GameView software exported Chart 5 and Chart 6, for the player 1 and player 2 respectively. Under the general rule on the line charts, it is concluded that the dominant strategies of the game for both players are weak.

Finally, regarding the resolution of the third game of the MTO problem, as shown in Table 9, two Nash equilibriums are identified. The first refers to the Nash equilibrium in the case that the load is delivered later than the predetermined time both at the port of Thessaloniki and at the port of Ningbo (late, late). The second Nash equilibrium refers to the situation where the load is delivered at predetermined times (on time, on time). From the above, it is easily

Chart 5: Line chart of player 1 strategies for the 3rd game of the MTO problem

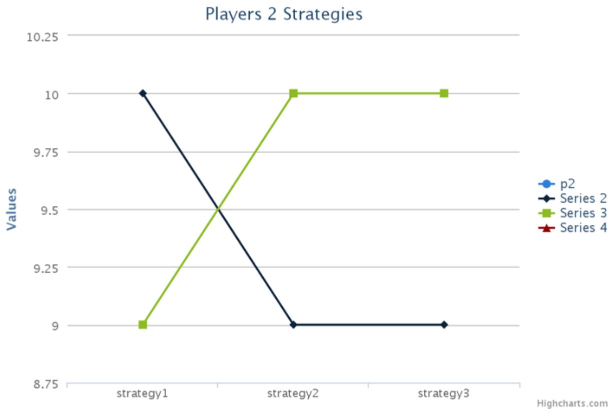

Chart 6: Line chart of player 2 strategies for the 3rd game of the MTO problem

understood that the first Nash equilibrium is not the optimum solution, which proves that the Nash equilibrium is not always the most efficient solution. In contrast, the second Nash equilibrium is an optimal solution of the game since both players are rewarded the maximum (10 utility units). Additionally, it is worth noting that the second Nash equilibrium is Pareto-optimal since both players benefit, with ten utility units respectively, and no one wants a different result.

Table 9: Nash equilibrium of the 3rd game of the MTO problem

7	10	9	9	
7	9	10	10	
6	9	9	10	

As for the fourth game, the MTO payoffs concerning the payment of the Ningbo port to the receipt and disposition of the load were defined, as well as the port of Ningbo payoffs in the management and delivery of the load to the transport company B after clearance of. It is noted that in the case of clearance delays attributable to the Ningbo port, there is no penalty to pay. For example, if the MTO is on time, namely the load reaches to the Ningbo port to the predetermined time, but the port of Ningbo delays the delivery of the cargo to the transport company B, the MTO is rewarded with seven utility units and the Ningbo port with ten utility units. Otherwise, if the load is delivered to the port of Ningbo later than the predetermined time, then the MTO is rewarded with ten units of utility, since no storage costs exist, while the port is rewarded with nine utility units, as included in the management costs.

Table 4:4th game of the MTO problem

MTO PROBLEM		PORT B	
		LATE	ON TIME
MTO	LATE	7, 9	10 , 9
	ON TIME	7 , 10	10, 10

Then, since the table of that game developed with the help of the GameView software (Table 11), it is observed that for both players all strategies are dominant. This is because in this game the payoffs of the strategies for both the MTO and the port of Ningbo are exactly alike regardless of the strategy the other player is going to follow. Thus, the strategies of the MTO reward them with seventeen utility units each, while the Ningbo port strategies reward it with nineteen utility units each.

Table 11: Dominant strategies of the 4th game of the MTO problem

7	9	10	9	Payoff p1:17
7	10	10	10	Payoff p1:17
	Payoff p2:19		Payoff p2:19	

In addition, Figure 4 shows the exact percentages of payoffs for every possible strategy of the MTO and the port of Ningbo.

Player 1:	Player 2:
Payoff p1 Strategy 1,1 : 41.18 %	Payoff p2 Strategy 1,1 : 47.37 %
Payoff p1 Strategy 1,2 : 58.82 %	Payoff p2 Strategy 1,2 : 52.63 %
Payoff p1 Strategy 2,1 : 41.18 %	Payoff p2 Strategy 2,1 : 47.37 %
Payoff p1 Strategy 2,2 : 58.82 %	Payoff p2 Strategy 2,2 : 52.63 %
Payoff strategy 1 : 50 %	Payoff strategy 1 : 50 %
Payoff strategy 2 : 50 %	Payoff strategy 2 : 50 %
Highest Payoff stategy:17	Highest Payoff stategy:19
Lowest Payoff stategy:17	Lowest Payoff stategy:19

Figure 4: Percentage of payoffs for the strategies of the 4th game of MTO problem

Also, the pie chart of the two players (chart 7 and chart 8) shows that each strategy takes 50% as a possible choice since each of the two strategies have exactly the same payoffs.

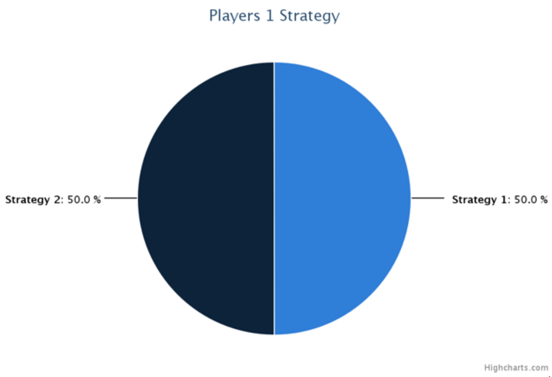

Chart 7: Pie chart of player 1 strategies for the 4^{th} game of the MTO problem

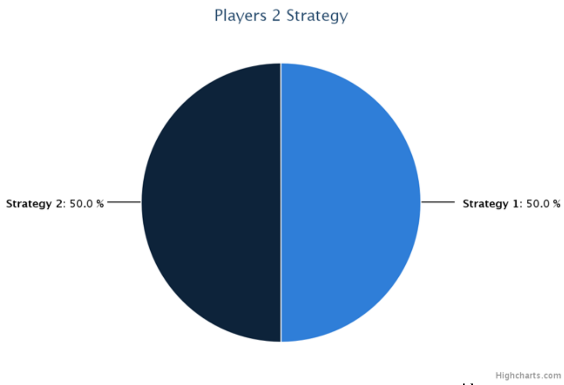

Chart 8: Pie chart of player 2 strategies for the 4^{th} game of the MTO problem

Finally, regarding the resolution of the fourth game of the MTO problem, as shown in Table 12, it is observed that all strategies are Nash equilibrium of the game. Of course, it is easily seen that both players would be preferable to the second strategy (on time, on time), since it is Pareto-optimal solution, and reward them with the maximum efficiency, namely ten utility units for each player.

Table 12: Nash equilibrium for the 4^{th} game of the MTO problem

7	9	10	9	
7	10	10	10	

Completing the MTO problem, in the fifth game the payoffs of the MTO were defined on payment of the transport company B for the receipt and delivery of the load to the merchant in the city of Ningbo, and the payoffs of the transport company B, which relate to the management and the delivery of fruit load on the fruit merchant, once the process of clearance (Table 13) has been completed. In this game, there is the case scenario of the delivery of load to the transport company B earlier than the predetermined time, due to faster than expected clearance and the case scenario in which the transport company B delays the delivery of the load either due to a malfunction of the port of Ningbo, or because of its own fault. In the latter case, there are specific sanctions that are predefined in the contracts signed. Moreover, it is considered that there are no discounts in the case of crude clearance because of the port fault. So for example, if the MTO is in time but transport company B delays in load delivery to its own fault, the MTO is rewarded with eight utility units and transport company B with seven utility units. Otherwise, if the load is ready for the transfer earlier than the predetermined time, but transport company B receives the load at the predetermined time, then the MTO is rewarded with nine utility units, while transport company B is rewarded with ten utility units, as acting within the framework of their agreement.

Table 5: 5th game of the MTO problem

MTO PROBLEM		TRANSPORTER B			
		LATE PORT	**LATE TR**	**ON TIME**	**EARLY**
MTO	**LATE**	8 , 10	8 , 7	8 , 11	8 , 10
	ON TIME	8 , 10	8 , 7	10 , 10	10 , 11
	EARLY	7 , 10	7 , 7	9 , 10	11 , 11

In the following table (Table 14), it is observed that both players have a dominant strategy. For the MTO a dominant strategy (on time) is observed rewarding him with thirty-six utility units. For transport company B a dominant strategy (early) is observed rewarding it with thirty two utility points.

Table 14: Dominant strategies of the 5th game of the MTO problem

8	10	8	7	8	11	8	10	Payoff p1:32
8	10	8	7	10	10	10	11	Payoff p1:36
7	10	7	7	9	10	11	11	Payoff p1:34
	Payoff p2:30		Payoff p2:21		Payoff p2:31		Payoff p2:32	

In addition, Figure 5 shows the exact percentages of payoffs for every possible strategy of the MTO and transport company B which will deliver the goods to the merchant in the city of Ningbo.

Player 1:
Payoff p1 Strategy 1,1 : 25 %
Payoff p1 Strategy 1,2 : 25 %
Payoff p1 Strategy 1,3 : 25 %
Payoff p1 Strategy 1,4 : 25 %
Payoff p1 Strategy 2,1 : 22.22 %
Payoff p1 Strategy 2,2 : 22.22 %
Payoff p1 Strategy 2,3 : 27.78 %
Payoff p1 Strategy 2,4 : 27.78 %
Payoff p1 Strategy 3,1 : 20.59 %
Payoff p1 Strategy 3,2 : 20.59 %
Payoff p1 Strategy 3,3 : 26.47 %
Payoff p1 Strategy 3,4 : 32.35 %

Payoff strategy 1 : 31.37 %
Payoff strategy 2 : 35.29 %
Payoff strategy 3 : 33.33 %
Highest Payoff stategy:36
Lowest Payoff stategy:32

Player 2:
Payoff p2 Strategy 1,1 : 33.33 %
Payoff p2 Strategy 1,2 : 33.33 %
Payoff p2 Strategy 1,3 : 33.33 %
Payoff p2 Strategy 2,1 : 33.33 %
Payoff p2 Strategy 2,2 : 33.33 %
Payoff p2 Strategy 2,3 : 33.33 %
Payoff p2 Strategy 3,1 : 35.48 %
Payoff p2 Strategy 3,2 : 32.26 %
Payoff p2 Strategy 3,3 : 32.26 %
Payoff p2 Strategy 4,1 : 31.25 %
Payoff p2 Strategy 4,2 : 34.38 %
Payoff p2 Strategy 4,3 : 34.38 %

Payoff strategy 1 : 26.32 %
Payoff strategy 2 : 18.42 %
Payoff strategy 3 : 27.19 %
Payoff strategy 4 : 28.07 %
Highest Payoff stategy:32
Lowest Payoff stategy:21

Figure 5: Percentage of payoffs for the strategies of the 5th game of the MTO problem

Furthermore, in order to determine whether the dominant strategies are strict or weak, through the GameView software exported Chart 9 and Chart 10 for the player 1 and player 2 respectively. From the stacked column charts of the two players, it is observed that since the payoffs with the same colors are not greater in any strategy related to the other one of each player, there isn't a strictly dominant strategy, while dominations of the second strategy (on time) for the first player and of the third strategy (on time) for the second player, are weak against others.

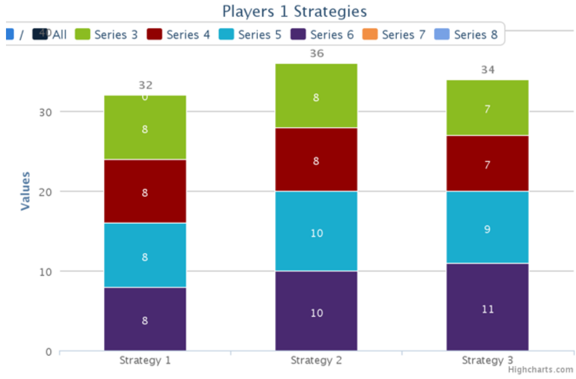

Figure 9: Stacked Column chart of player 1 strategies for the 5th game of the MTO problem

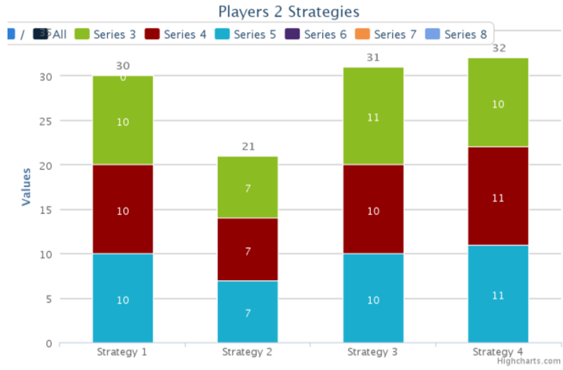

Figure 10: Stacked Column chart of player 2 strategies for the 5th game of the MTO problem

Finally, regarding the resolution of the fifth game of the MTO problem, as shown in Table 15, a Nash equilibrium is identified, which, as noted, does not coincide with any dominant strategy of either player, but concerns the strategy in which the load is supplied earlier than the predetermined time by both the MTO and transport company B (early, early) and during which everyone derives eleven utility units.

Table 15: Nash equilibrium of the 5th game of the MTO problem

8	10	8	7	8	11	8	10	
8	10	8	7	10	10	10	11	
7	10	7	7	9	10	11	11	

Conclusions

It is a fact that transport plays one of the most important roles in the quality of the supply chain services and consequently in the effectiveness and efficiency of the enterprises themselves. In the context of quality, transport must meet certain criteria such as reliability, accuracy in time, speed and cost to meet the increased demands of a globalized and yet competitive market.

In order to optimally meet these requirements operates the MTO who is also the manager of the transfer of products from the time of receipt by the supplier until the moment of their delivery to the final customer. The role of the MTO is crucial not only because it selects the best path to each means of transport, but also as a result of various interactions with the intermediate parties, they will have to design, plan and coordinate the transfer in its entirety. In this point it is game theory that is used as a very useful tool that allows the MTO to analyze all possible versions of the complex interactions that exist at every stage of transfer and take the more correct decision to ultimately maximize its benefits. This is exactly presented and analyzed in this study by identifying the best strategy to be followed by the MTO to maximize its benefits, taking into account certain rules of the game relating to any deviations from the predetermined time and cost.

Summing up, the results of the MTO problem as previously analyzed, initially, as a dominant strategy for both the MTO and the producer from Katerini city appear to be the delivery of the load to China merchant earlier than the predetermined time. Then, on the interaction of the MTO with the transport company A, the dominant strategy for the first is the receipt of the load from the transport company A either earlier or at the predetermined time, while the dominant strategy for the second is the delivery of load to the port of Thessaloniki at the predetermined time. Subsequently, on the interaction of the MTO with the port of Thessaloniki, the dominant strategy for both appears to be the receipt and delivery of the load from the port at the predetermined time. Furthermore, regarding the interaction of the MTO with the port of Ningbo, although all strategies for both appear to be dominant, the delivery of the load from the port of Ningbo and the delivery to the transport company B at the predetermined time is preferred. Finally, on the interaction of the MTO with the transport company B, the dominant strategy for the first appears to be the delivery of the load to the transport company B at the predetermined time, while the dominant strategy for the second is to deliver the load to the fruit merchant in the city of Ningbo earlier than the predetermined time.

In conclusion, despite the fact that these strategies are the most profitable for all the players participating in the games of the MTO problem, it should not be omitted that because of all the possible obstacles they might forced to follow other strategies. However, through the application of game theory the payoffs for each player and for each possible case are presented, so that every player is able to predict the next move, and especially the MTO due to the particular role and interaction that he has with all the players depending on the outcome of the previous game at a time.

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[1] This online game theory software developed by the same author Pavlidis Konstantinos