Applying Game Theory in Procurement. An Approach for Coping with Dynamic Conditions in Supply Chains

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Abstract Producing companies are facing continually changing conditions accompanied by higher requirements with respect to the flexible configuration of their supply chain. The challenge resulting from this initial situation is to develop systems that have the availability of adjusting their planning procedures and aims depended on the situation and therefore accommodate the increasing demand for flexibility. To address this challenge game theory seems to be a new and promising approach.

The aim and added-value of the research work described here is to develop a decision model for the area of procurement using solutions concepts of game theory. Especially in times of high volatility such a decision model can support material requirements planners better than today's common selective planning logics. In this paper the model to be solved by game theoretic solution concepts is presented. A research study has been conducted which proved the need for combining existing methods of procurement quantity calculation by means of game theoretic solution concepts. Some of the results of this study are presented in this paper. In the last part of the paper a structure for classifying game theoretic models is presented. This structure should support in selecting the appropriate solution concept for real-life decision-situations and is able to support in any practical application-field finding out the most appropriate game theoretic solution concept.

Keywords: Supply Chain dynamics, procurement quantity calculation, flexibility, game theory.

1. Introduction

Today, companies face increasing dynamic conditions and volatile markets. Varying demands, shorter product lifecycle times and increasing diversity of products as well as unsteady economic situations force enterprises to react more flexible compared to some years ago (cf. Daxböck et al., 2011, p. 7; Schuh et al., 2012, p. 3; Stich et al., 2012, p. 123).

Central planning approaches regarding production and logistics processes are matched to a particular moment of the enterprises conditions. These planning-oriented systems are not able to react spontaneously on changing conditions (cf. Schmitt et al., 2011, p. 748). But exactly the ability to react flexibly becomes more and more a key factor of success for enterprises. Other approaches reduce central planning in favour of decentralised activities, which provide better possibilities to flexibly react according to the current situation (cf. Schmitt et al., 2011, p. 749). Thus integration into the value-added process is given in decentralised approaches. Nevertheless decentralised approaches have a big disadvantage as well. Central planning approaches often result in best solutions for the considered scope, a so called global optimum. Decentralised activities are performed with a smaller perspective as the decision maker takes into consideration for example only the processes he is responsible for. Hence in decentral approaches a global optimum will often not be achieved.

Therefore it is necessary to find an optimal way between detailed central planning and spontaneous decentral reactions to occurred changes for enabling successful management of production and logistics processes. As a suitable approach for solving this problem, self-optimising mechanisms could be integrated into the production planning and control as well as in supply chain processes (cf. Behnen et al., 2011, p. 103). Self-optimising systems are "systems that are able to effect independent ("endogenous") changes of their inner states or structure based on varying input conditions or interferences" (Wagels and Schmitt, 2012, p. 162). Self-optimising systems have the capability to react autonomous and flexible to changing boundary conditions. They continuously carry out three activities (cf. Brecher et al., 2011, p. 13):

1. analysis of the current situation,
2. determination of objectives and
3. adjustment of the behaviour of the system to reach the defined objectives.

The project "Cognition-enhanced, Self-Optimising Production Networks" which is part of the Aachen Cluster of Excellence (CoE) founded by the German Research Foundation (DFG, Deutsche Forschungsgemeinschaft) focusses on self-optimising production planning and control from the level of machine control up to the level of supply chain management. In this regard both, human decision making as well as integrating the perspectives of production and quality management will be considered. Test-beds for experimental research in a real production environment to validate and enhance the outcome will be build. The objective is to develop prototypes of cybernetic solution components based on self-optimising feedback loops.

2. Problem statement

The described need for reacting more flexible is proven by a study which has been published by Daxböck et al. 2011. The results of this study show that in 2011 cost-efficiency has been the most-important target for producing companies, but in future flexibility will be the most important factor of success (cf. Daxböck et al., 2011, p. 7). Nevertheless, only 43% of the respondents suppose that their company is able to react sufficiently flexible. Regarding the functional division – namely stock-keeping, distribution, production and procurement – the division of procurement has been identified to be the one with the highest potential for improvement (cf. Daxböck et al., 2011, p. 9).

When performing central approaches in supply chains with different companies, information barriers occur (cf. Qing-min and Lin, 2009, p. 1457). Thus decentral approaches seem to be more promising for achieving more flexibility in supply chains. In the following an approach for achieving more flexibility with its focus on procurement, particularly procurement quantity calculation, is presented.

Today planning processes in the area of procurement quantity calculation are generally matched to a particular moment of the enterprises conditions. Thus these planning processes are applied continuously regardless of changes in the conditions. If at all modifications are conducted, these are time-consuming and costly for the enterprises (cf. Schmitt et al., 2011, p. 748-749). Need for action exists not only regarding the selection of appropriate planning processes, but also in terms of the selection of appropriate parameter-settings for the planning processes. Procurement managers generally rely on the parameters and methods that are set in their enterprise resource planning systems and they are overextended with the selection and adaption of the parameter-settings (cf. Schmidt, 2012, p. 45).

Solution concepts of game theory can help in supporting procurement managers in this challenge. Thus this constitutes a promising approach for obtaining more flexibility in the area of procurement. By applying game theoretic solution concepts the continuous verification of the planning procedures and parameter-settings, which are set in the enterprise resource planning system of the company, could be supported and changes could be carried out. Thus by applying game theoretic solution concepts it is possible to receive an improved decentral coordination of the entities in a supply chain. This approach derives benefit both for supply chains with legally independent companies and for deliveries between different locations of the same company. The approach could be applied for any industrial sector.

3. State of the art

Already in 1944 von Neumann and Morgenstern, two of the pioneers of game theory, realised the applicability of game theory for analysing economic issues (von Neumann and Morgenstern, 1944). The development of game theory was inter alia based on the work of other key players, such as John Nash (Nash, 1953), Reinhard Selten (Selten, 1978) or John Harsanyi (Harsanyi, 1967).

Game theory has been widely studied in the application of supply chain management, but however, has been used in most cases only as an analytical tool (see for example Hennet and Arda, 2008; Chen et al., 2006; Leng and Parlar, 2005; Abad, 1994; Kohli and Park, 1989; Jordan et al., 2007; Viswanathan and Wang, 2003; Li et al., 1996). Thereby by means of game theoretic models it is shown, that cooperation brings benefit for all participants in a supply chain. In other surveys the influence of the transfer of information is analysed. Additionally rules for distributing savings are developed and it is analysed which conditions have to be met for coalitions to remain stable. Cooperative games, where negotiating processes are analysed, are best developed (cf. Herbst, 2007, p. 85). Drozak describes that game theory is used in purchasing nowadays, but he points out the need for a method that is tailored to the qualifications of purchasers (cf. Drozak, 2013, p. 32). Drozak refers with this requirement to netotiating processes as well.

In game theoretic literature a lack of application of game theoretic solution concepts for improving decisions that are adopted over time could be recognised (cf. Fischer, 1997, p. 10). This application area has been identified by Leng and Parlar already in 2009 as an important field for future research works (cf. Leng and Parlar, 2009, p. 212). Likewise the situation of imperfect information in game theoretic applications is so far not sufficiently pervaded (cf. Herbst, 2007, p. 87).

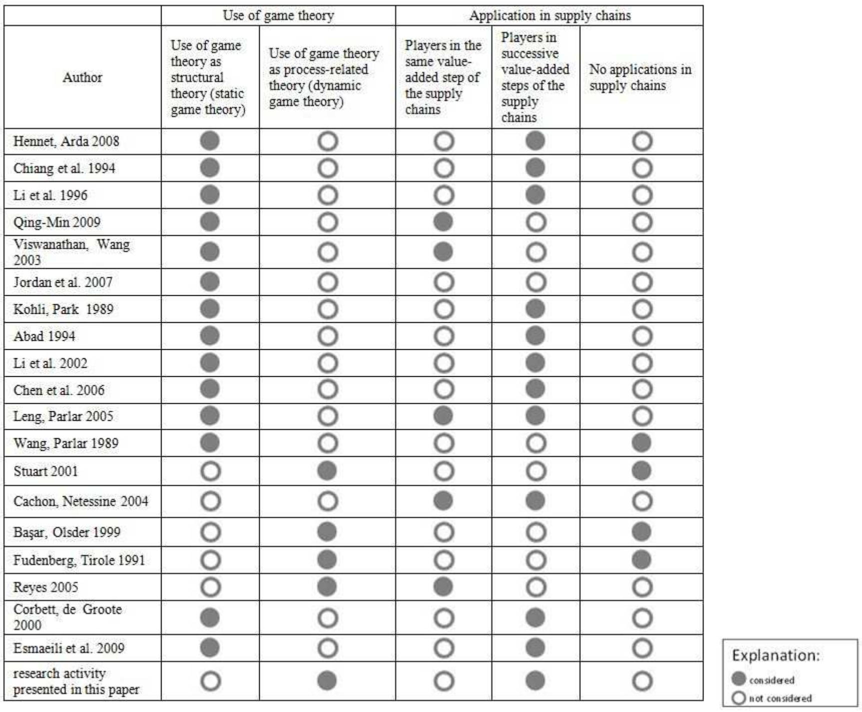
Based on the current state of the art concerning the application of game theoretic solution concepts a deficit could be seen especially with focus on purchasing and inventory management. Indeed Wang and Parlar have already asked in 1989 for more attention in game theoretic applications especially in this field (cf. Wang and Parlar, 1989, p. 17), but up to now this claim has not been satisfied. Moreover existing surveys using game theory in purchasing focus on deterministic demand (cf.

Sarmah et al., 2006, S. 13). In contrast to this in the approach, which is presented in this paper, fluctuating demand will be considered.

In addition there is a need for dynamic methods for procurement quantity calculation and dynamic calculation of batch sizes. That is why an adaption of parameter-settings and adaption of methods have to be done manually by procurement managers when boundary conditions such as sales fluctuations occur (cf. Stumvoll et al., 2013, p. 570; Schmitt et al. 2011, p. 748 – 749).

In the context of the research activities presented in this paper, the focus lays on the process-related aspects of game theory and players, who are in successive value-added steps of a supply chain. Table 1 summarizes the results of the survey of the state of the art in comparison to the research described in this paper. This points out deficits in this area of the research activities.

Table 1: State of the art and the research activity presented in this paper



	Use of game theory		Application in supply chains		
Author	Use of game theory as structural theory (static game theory)	Use of game theory as process-related theory (dynamic game theory)	Players in the same value-added step of the supply chains	Players in successive value-added steps of the supply chains	No applications in supply chains
Hennet, Arda 2008	●	○	○	●	○
Chiang et al. 1994	●	○	○	●	○
Li et al. 1996	●	○	○	●	○
Qing-Min 2009	●	○	●	○	○
Viswanathan, Wang 2003	●	○	●	○	○
Jordan et al. 2007	●	○	○	○	○
Kohli, Park 1989	●	○	○	●	○
Abad 1994	●	○	○	●	○
Li et al. 2002	●	○	○	●	○
Chen et al. 2006	●	○	○	●	○
Leng, Parlar 2005	●	○	●	●	○
Wang, Parlar 1989	●	○	○	○	●
Stuart 2001	○	●	○	○	●
Cachon, Netessine 2004	○	○	●	●	○
Başar, Olsder 1999	○	●	○	○	●
Fudenberg, Tirole 1991	○	●	○	○	●
Reyes 2005	○	●	●	○	○
Corbett, de Groote 2000	●	○	○	●	○
Esmaeili et al. 2009	●	○	○	●	○
research activity presented in this paper	○	●	○	●	○

Explanation:
● considered
○ not considered

4. Problem formulation

In the following the model which is solved by the methods of procurement quantity calculation is presented. First some assumptions for the setting will be depicted:

Only one product in the supply chain will be considered and is procured independent of other products. Only one distributor delivers the product. The demand of the product is known and is given as input of the model per single period t for the whole period under review. This means that the result of the demand calculation is not in focus in the model itself. Over all single periods for the whole period under review the demand can be constant (stable, static demand) or fluctuating (dynamic demand).

Further assumptions for the models are:

- Stock-outs are not allowed
- Fixed costs for procurement (Kf) are constant
- Each order arrives directly after triggering and has direct effect to the stock
- The procurement price is constant
- Storage costs in percentage (l) and the interest rate (z) are constant
- Inventory *S0* at the beginning of the first period under review is 0
- Inventory *sn* at the end of the whole period under review is 0

Let K^* denote the objective function and x_t the quantity to be procured in period t. The demand for period t is denoted by b_t and let M be an arbitrary big figure ('big M'). Furthermore let $\mu_t$be a binary variable with $\mu_t = 1$, if an order is put in period t and 0 otherwise. Then the objective function for procurement quantity calculation for a period under review from period $i, \ldots, n$ is:

$$\text{Minimise} \quad K^* = \sum_{t=i}^{n} (K_f * \mu_t + (z+1) * s_t) \tag{1}$$

The side conditions for the above given objective function are:

$$s_t = s_{t-1} + x_t - b_t \tag{2}$$

$$x_t - M * \mu_t \leqslant 0 \tag{3}$$

$$x_t \geqslant 0 \tag{4}$$

$$s_t \geqslant 0 \tag{5}$$

$$s_i, \quad s_n = 0 \tag{6}$$

with:

$$\mu_t \in \{0, 1\} \tag{7}$$

$$t = i, i+1, i+2, ..., n \tag{8}$$

For the problem definition see for example Tempelmeier (Tempelmeier, 2006, p. 138) or Neumann (Neumann, 2004, p. 594 – 595).

The objective function K^* is composed of the ordering costs and the storage costs. The procurement costs as a product of the quantity to be procured and the price do not have to be considered in more detail in the procurement quantity calculation and do not need to be a component of the objective function K^* since they are a constant over the whole period under review. Consequently they have no influence on minimising the overall costs K (see for example Neumann, 2004, p. 594). In case of static demand, b_t, is equal to the mean demand $\overline{\text{b}}$.

The first side condition (equation 2) is also called storage-balance-equation. It says that the inventory s_t at the end of period t is a result of the inventory s_{t-1}

at the end of period $t-1$, the quantity to be procured in period $t\,(x_t)$ and the demand for period t (b_t) (see for example Neumann, 2004, p. 593–594). The binary variable μ_t is 1, if an order is put in period t and 0 otherwise. This is achieved by equation (3) in connection with the minimising provision of the objective function (cf. Tempelmeier, 2006, p. 139). Thereby let M be an arbitrary big figure, which has to be at least so big that the quantity to be procured in each period t (x_t) is not restricted (cf. Tempelmeier, 2006, p. 139). The third side condition (equation 4) states that there are no negative quantities to be procured. By equation (5) is stated that inventory cannot be negative.

The model presented in equation (1) to (8) describes the procurement quantity calculation and is called single-level uncapacitated lot sizing problem (SLULSP) (cf. Tempelmeier, 2006, p. 138). For the purpose of analysing the influence of different logistics parameters and random incidents the above described assumptions have to be extended as in reality for example stock-outs occure. These and other criterions which have to be considered but are not incorporated in the SLULSP have been taken into account by use of an additional model.

5. Research study: Applicability of methods for procurement quantity calculation under different conditions

In the literature exist a lot of different heuristic methods and one optimal method for solving the presented SLULSP. As the SLULSP describes the problem of procurement quantity calculation, these heuristics are methods for procurement quantity calculation. The most established methods are the method from Wagner and Within (WW), the Least Unit Cost Method (LUC), the heuristic from Silver and Meal (SM), the heuristic from Groff (Groff), the Least Total Cost Method (LTC), the Incremental Order Quantity Method (IOQ), the method of Periodic Order Quantity (POQ) and the McLaren Order Moment (MOM).

Existing surveys regarding the applicability of the heuristics do not analyse all possible types of demand (static demand, seasonal fluctuating demand, sporadic demand and trend in the demand) and especially uncertainty in logistics parameters such as

- the demand calculation was not right
- the supplier delivered less items than ordered
- the delivery arrives delayed

have not been in focus in existing surveys, but exactly these uncertainties become more relevant in practice nowadays. Game theoretic solution concepts can help especially under dynamic conditions like these as it was pointed out at the beginning of this paper. For setting up a decision model thus in a first step the influence of these logistics parameters was investigated. As the assumptions of the SLULSP as described in the previous section are not sufficient for these investigations, the model had been expanded to analyse the influence of different logistics parameters and random incidents. As mentioned above for example stock-outs need to be integrated into the model by use of a further model which displays the inventory.

By use of these two models for the approach presented in this paper, the above given methods of procurement quantity calculation have been implemented to investigate the influence of the logistics parameters for the different methods on the

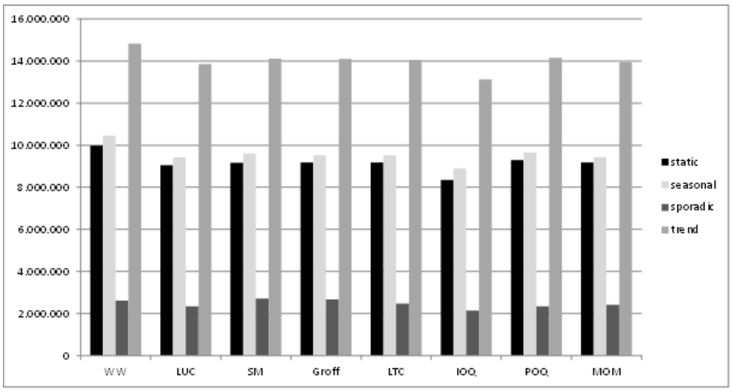


Fig. 1: Impact of the type of demand per method of procurement quantity calculation

result of the objective function of the SLULSP. First of all it could be seen, that the types of demand have considerably impact on the results (see Figure 1).

The logistics parameters under consideration are listed in the following. Additionally the range for the variation is given for each parameter (see table 2).

Table 2: Logistics parameters under review in the survey and their range

Logistics parameters	minimum	Maximum
price (monetary units)	1	50
storage costs (percentage)	12	35
fixed costs for procurement (monetary units)	437,5	5292
stock-out costs (percentage)	50	500
replacement time (periods)	1	21
planning interval (periods)	25	90
Length of the planning horizon (periods)	140	365
delay in delivery (probability; periods)	0; 0	0.5; 10
shortshipment (probability; percentage)	0; 0	0,5; 0,5
deviation of demand (expected value; standard deviation)	0; 0	0; 10

The results of the study confirm the relevance of combining these well-known methods of procurement quantity calculation by use of game theoretic solution concepts. The sequence of applicability of the methods could be seen with regard to the result in the objective function expressed in monetary units. For example considering different length of the planning horizon from 140 periods up to 365 periods when the demand is stationary, seasonal or has a trend the objective value of the IOQ-Method becomes higher (see Figure 2). In contrast the objective value becomes lower when the methods LUC, SM, LTC, Groff, POQ or MOM are applied under a seasonal demand. Considering a trend in demand it could be seen, that the method POQ causes the second highest costs when the length of the planning horizon is 365 periods. With a shorter planning horizon of 140 periods the methods WW, Groff and SM all cause higher costs than the method POQ. So in this case when all the other parameters remain stable and only the length of the planning horizon is varied the applicability of the methods POQ, Groff and SM is inverted.

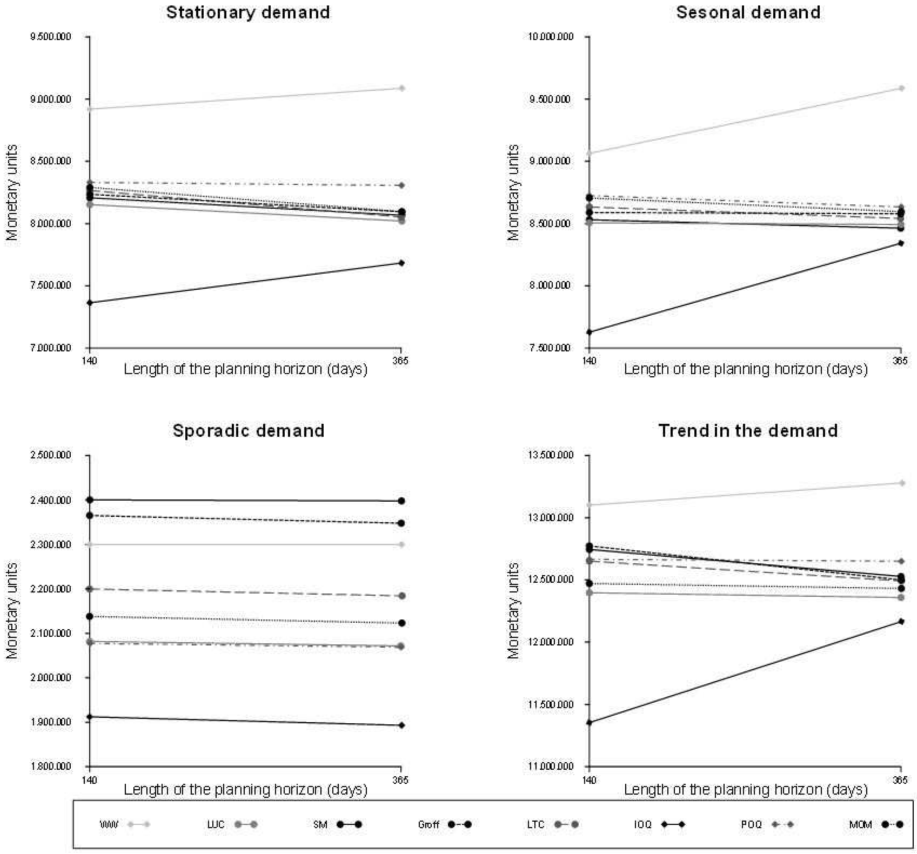


Fig. 2: Influence of the length of the planning horizon on the objective value in different demand situations

In real-life situations in most cases more than only one parameter changes. For this purpose the correlations between different logistics parameters have been investigated as well. In Figure 3 for example the correlation of the planning interval and the deviation of demand could be seen. A deviation of demand is given if the demand of the product was incorrect beforehand. When the method WW is applied and there is a trend in demand the correlation of these two parameters is marginal (see Figure 3, left side) but if the method IOQ is applied in the same situation the correlation of these two parameters is much bigger (see Figure 3, right side). In the second case when there is no deviation in demand (e.g. the demand was right beforehand) the objective value is much higher with a bigger planning interval. In contrast in case the demand was not calculated right beforehand the spread of the objective value is way smaller.

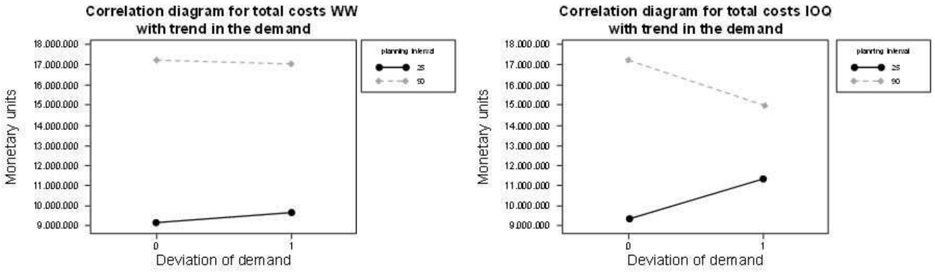


Fig. 3: Correlation Diagrams: Influence of length of the planning interval combined with devation of demand with a given trend in demand

As it could be seen by these two examples, the objective values generated by the methods differ depending on the given environmental conditions. A sophisticated analysis of the influence of the logistics parameters is thus an essential finding for the decision model which will be developed and later on solved by game theoretic solution concepts.

By means of the conducted investigations it became clear that none of the well-known methods for procurement quantity calculation provides the best solution for all combinations of the logistics parameters under review. Thus these parameters, their combination as well as uncertainties have got an effect on the appropriate method for procurement quantity calculation. Furthermore it could be seen that the influence of the logistics parameters under consideration differs from method to method. The influence on the objective value of the parameters differs from method to method. This could be seen for example in Figure 2.

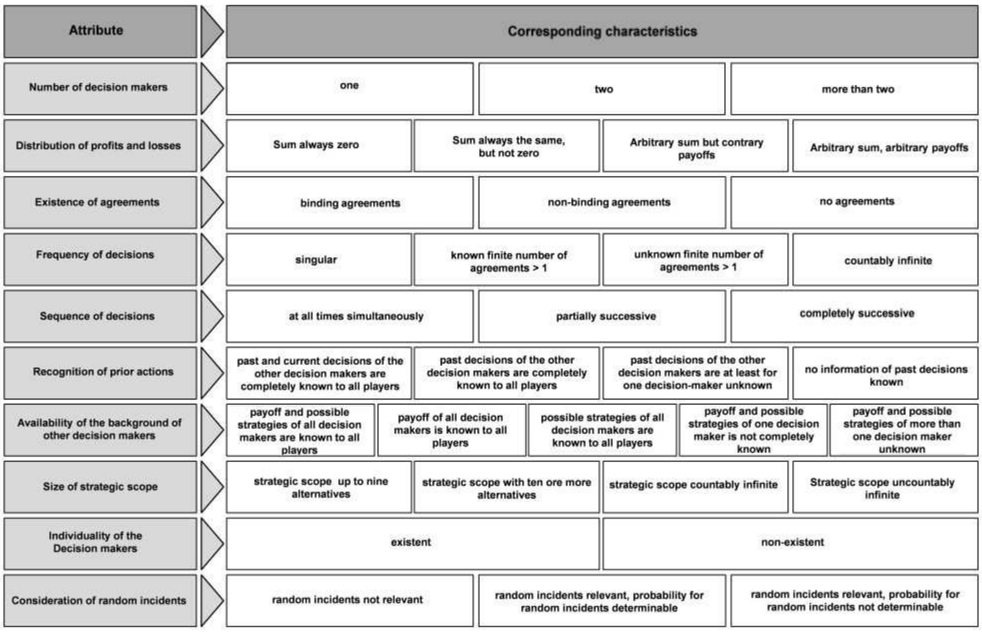
Thus through the investigations it was approved that game theoretic solution concepts should support in choosing the appropriate method under given conditions, as it will be done by the approach presented in this paper.

6. A structure for classifying game theoretic models for choosing appropriate solution concepts

Nowadays in game theory there exist a lot of different alternative models that are suited for representing diverse real-life-situations. It is beyond dispute that the type of game (i.e. the game theoretic model) has essential influence on the appropriate game theoretic solution concept (see for example Schiml, 2008, p. 26). Thus when applying game theory to real-life decision-problems the first very important step is to decide which solution concept is the most suitable for the decision-problem at hand.

To reach this goal, a scheme which can help classifying game theoretic solution concepts is needed. This scheme has to be based on the different attributes of game theoretic models as these models have essential influence on the solution concepts. It has been found out, that no such scheme which is comprehensive exists in game theoretic literature. A lot of authors list different attributes of game theoretic models with some corresponding characteristics. In the majority of cases these explanations take place only in a textual way (see for example Herbst, 2007, p. 84 – 86; Kaluza, 1972, p. 21 – 49). Other authors give some game theoretic models in form of a list (see for example Lasaulce and Tembine, 2011, p. 15; Kuhn, 2007, p. 50). For each of the considered types of games Vogt lists two different corresponding characteristics (see Vogt, 2013, p. 300). Only two authors describe the different game theoretic models and their corresponding schemes in form of a structured scheme: Marchand gives such a scheme but for each type he depicts only two different corresponding characteristics (see Marchand, 2012, p. 36). Pickel et al. sum up different game theoretic models with their characteristics in a diagram, but this diagram is not structured consistently (see Pickel et al., 2009, p. 67).

Independent from the form of representation none of the above mentioned compositions give an exhaustive description of all existing game theoretic models and their corresponding characteristics. Thus to obtain a comprehensive and well-structured description of the attributes and corresponding characteristics of game theoretic models a morphology has been developed in the context of the research work presented in this paper. The morphology is depicted in Figure 4 and is described in the following.



Attribute	Corresponding characteristics				
Number of decision makers	one	two	more than two		
Distribution of profits and losses	Sum always zero	Sum always the same, but not zero	Arbitrary sum but contrary payoffs	Arbitrary sum, arbitrary payoffs	
Existence of agreements	binding agreements	non-binding agreements	no agreements		
Frequency of decisions	singular	known finite number of agreements > 1	unknown finite number of agreements > 1	countably infinite	
Sequence of decisions	at all times simultaneously	partially successive	completely successive		
Recognition of prior actions	past and current decisions of the other decision makers are completely known to all players	past decisions of the other decision makers are completely known to all players	past decisions of the other decision makers are at least for one decision-maker unknown	no information of past decisions known	
Availability of the background of other decision makers	payoff and possible strategies of all decision makers are known to all players	payoff of all decision makers is known to all players	possible strategies of all decision makers are known to all players	payoff and possible strategies of one decision maker is not completely known	payoff and possible strategies of more than one decision maker unknown
Size of strategic scope	strategic scope up to nine alternatives	strategic scope with ten ore more alternatives	strategic scope countably infinite	Strategic scope uncountably infinite	
Individuality of the Decision makers	existent	non-existent			
Consideration of random incidents	random incidents not relevant	random incidents relevant, probability for random incidents determinable	random incidents relevant, probability for random incidents not determinable		

Fig. 4: Structure for classifying game theoretic models for choosing appropriate solution concepts

Ten attributes have been identified which differentiate game theoretic models. By the **number of decision makers** it is meant how many people participate in the decision. If there is only one decision maker the model could rather be assigned to decision theory than game theory. But as some authors assign these models to game theory, this characteristic is listed in the morphology presented here. In game theoretic models not in all cases only two decision makers are incorporated in the model. There are a lot of situations with more than two decision makers as well.

Another attribute when analysing decision situations is the **distribution of profits and losses**, which could be expected as a result of the decision. The corresponding characteristics of this attribute were derived from the types of games zero-sum-games, nonzero-sum-games, constant-sum-games and strictly competitive games as all of these models could be differentiated by the attribute of how the profits and losses of the decision makers are distributed.

The **existence of agreements** is the third attribute which has been identified as an essential attribute when classifying game theoretic models and choosing the most suitable game theoretic solution concept. Looking at cooperative game theoretic models, binding agreements between the decision makers are declared. On the other hand in non-cooperative game theory these agreements could be non-binding or the decision makers make no agreements at all.

The number of repetitions in a game corresponds to the attribute **frequency of decisions** in the morphology given in Figure 4. This attribute, which refers to repeated games, has considerable impact on the applicability of the solution concept as well. If the game will not be repeated the decision maker will always chose the best choice for himself. But if a game is repeated all decision makers will be more willing to find best solutions for all of them as they are afraid of retaliation otherwise. In game theory, games with singular decision, a known finite number > 1 of games to be played, a unknown finite number of games to be played > 1 as well as games which have a countable finite number of repetitions could be differentiated.

Another important attribute to distinguish game theoretic models is the **sequence of decisions**. Meant by this attribute is if the decisions of the players in a game are performed simultaneously or successive. This refers to simultaneous and sequential move games.

Moreover game theoretic models could be classified by the information available to the players. In game theory there exist games with perfect or imperfect information. This is meant by the **recognition of prior actions**. Does every player know exactly which situation is on hand (i.e. past and current decisions of the other decision makers are completely known to all players) this is a game with perfect information. If at least one decision maker does not exactly know past decisions of the other players, this is called a game with imperfect information. Further characteristics of this attribute could be that past decisions of the other decision makers are completely known to all players or that no information of past decisions are know. Another deficit in information in game theoretic models could be caused by the **availability of the background of other decision makers**. As a first corresponding characteristic it is possible that the payoff and possible strategies of all decision makers are known to all players. These are games with complete information where every rational decision maker is able to calculate the best strategy for himself exactly. In contrast to these there are games with incomplete information. The corresponding graduation could be seen in Figure 4.

The strategic scope it the set of available strategies for a player. The **size of the strategic scope** can be distinguished by the criterion if the possible strategies could be depicted reasonable as a decision-matrix or game-tree. Theoretically every game-tree could be depicted unless it is infinite. Surveys show that up to nine alternatives could be processed by humans. Thus for a strategic scope of ten or more alternatives it does not seem to be reasonable to depict them as a decision-matrix or game-tree. For these cases as well as if the strategic scope is countably or even uncountably infinite reaction-functions from game theory could help solving such decision problems.

In evolutionary game theory no longer individual decision makers are in focus. Instead these models focus on populations and the members of a population are able to decide only in the way their genetic code allows. Thus regarding the attribute **individuality of the decision makers** it could be distinguished if the individuality is existent or not.

The last attribute in the morphology for classifying game theoretic models is the **consideration of random incidents**. In contrast to all other attributes this attribute could not be derived from the types of games directly. This attribute could be originary derived from decision-theory but is relevant in game theoretic models as well. If random incidents have to be considered in game theory, a decision maker has to determine the probability for the random incidents if possible. Therefore the corresponding characteristics of this atribute in the morphology are: random incidents are not relevant, random incidents are relevant and the probability for these could be determined and random incidents are relevant but the probability for random incidents could not be determined.

The developed morphology can support in carving out which game theoretic solution concept will help to solve the described problem statement of combining existing heuristics for the procurement quantity calculation for getting more flexibility in supply chains. Therefore the corresponding characteristic per attribute has to be identified for each game theoretic solution concept which is generally suited for solving the problem on hand. The same has to be done for the real-life-situation under review. Then structural similarities could be seen. This gives a structured basis for deciding which solution concept should be applied for solving the given problem later on.

7. Conclusion and further research-steps

In this paper at first a short introduction into the idea of applying game theoretic solution concepts for appropriate use of well-known methods of procurement quantity calculation had been given. In the next part in the state of the art in could be seen that there exists a lack in using game theory for improving and adapting decisions over time. Additionally a lack in applying game theory especially in purchasing and inventory had been identified. Solving the problem of procurement quantity calculation means to solve a SLULSP. Therefore the model was introduced in the next part of this paper. Some results of the conducted study regarding the applicability of the methods of procurement quantity calculation have as well been presented in this paper. This study made clear that changing parameters impact the objective value of the different methods for procurement quantity calculation significantly. Thus the relevance of the work presented here is approved. To enable choosing the most suitable method under given conditions the survey will be pursued in more detail to deduce concrete recommendations for switching the methods from these findings.

As a last step in this paper a structure for classifying game theoretic models to enable choosing the appropriate solution concept was presented. This morphology can help to answer the question of which game theoretic solution concepts can be applied in an application area – for example in procurement quantity calculation as regarded in this paper. For this purpose the solution concepts have to be opposed to the application area by the use of this morphology. By this it is ensured that exactly the solution concepts which are relevant in the application area of procurement are considered in the following research steps.

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