Selected Activity Coordination Mechanisms in Complex Systems

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Abstract. The article is a presentation of the research results regarding selected activity coordination mechanisms. The research was carried out independently and within the framework of a research project. Reference coordination models, which serve further simulation works, are their result. The article consists of several parts. The first part discusses the most important issues regarding coordination theory. The second part discusses activity coordination in complex systems, multi-agent systems. Selected activity coordination mechanisms and their comparisons were presented in the third part. The article is concluded with a summary.

Keywords: Coordination · Coordination mechanisms · Supply chain · Complex systems

1 Introduction

A supply chain, as a sequence of organisations collaborating to provide the largest possible amount of a product or service for the customer, can create very complex interrelation networks at every stage [1]. Supply chain management is defined as "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long term performance of the individual companies and the supply chain as a whole" [2]. But the supply chain management is a decision process that not only integrates all of its participants, but also helps to coordinate the basic flows: products/services, information and funds [3]. Coordination defined as the process of managing dependencies among activities. Starting with the individual activity it is easily recognized that the industrial reality contains a multitude of various activities. When focusing solely on individual activities, these might seem to have a generic value, for example considering a production or exchange activity [13].

The author was interested in the topic of activity coordination in the supply chain and undertook research on the topic in 2011. Up to now works, which have been documented in relation to several issues have been led:

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- Coordination in the Supply Chain - An Indication of Logistic Management – A Theoretical Approach, 2011 - It was noted that the effective coordination of activities of independent companies is the key to achieve flexibility and speed in completing the activities. These may become the source of the improvement of logistics processes as well as the competitive advantage necessary for processing on a global market. Weak coordination between the participants in the supply chain can cause a dysfunction of the operational activities.
- The Role of Coordination in the Supply Chain – Experimental Research, 2011 – It was observed that along with the acquisition of experience in the simulated supply chain, the number of verbal messages in total and the number of verbal task messages was subject to a decrease and the supervision (control) in the form of transferring verbal task messages (type: orders, guidelines) was weakened. Along with the gaining of experience, the internalization of standards takes place, i.e. the process of the systematic assimilation and acceptance of patterns of procedure, which are allocated to indicated conditions and are connected with the completion of the allocated rile in the supply chain. From this it follows that the more experienced participants of the supply chain, who achieved a certain level of identification and coordination with other elements in the system, require the relatively week level of control through verbal messages, with the maintenance of the expected quality and timely efficiency.
- Coordination Methods in the Supply Chain, 2012 – Four types of coordination have been distinguished and ten coordination techniques have been developed.
- Coordination in the Supply Chain – an Indication of Logistic Management, 2013 - The aim of the article is the indication of activity coordination techniques that are applied by the enterprises. Fifty enterprises, unrelated to each other in their business activities took part in the conducted research. The respondents had the possibility of indicating more than one answer. The application of three coordination techniques was most often noted: coordination (28 % indication), the application of six or seven techniques (4 % each) was least common. 16 % of the research respondents apply eight of the ten coordination techniques.
- Logistics Process Modelling in Supply Chain – algorithm of coordination in the supply chain – contracting, 2014 – The aim of the article is to discuss the selected process modelling methods in the supply chain on the example of one of the coordination mechanisms, i.e. contracting. In supply chain type structures, the coordination technique commonly referred to as contracting, is popular. This is a classic form of coordination in the case of a decentralized market. It can be applied in the case in which the order (undertaking or task to be accomplished) has a well defined structure of sub-orders or sub-tasks. It is also important to be able to subject the order to a decomposition into a series of sub-tasks [4].
- The meaning of activity coordination in the supply chain, 2014 – The presented results are a continuation of the research from 2013 and show the meaning and essence of coordination in the business environment. The respondents participating in the research indicating the significant impact of activity coordination on logistics at the operational level (1. activity coordination improves the processes occurring at this level, ca. 79 % - the total number of responses for I fully agree and I agree, 2. activity coordination decreases the order completion time, ca. 83 % - the total

number of responses for I fully agree and I agree) and point to the significant impact of activity coordination of the logistics carried out at the strategic level (activity coordination allows for the harmonisation of the applied logistics strategies, ca. 73 % - the total number of responses for I fully agree and I agree) [5].

- Reference models of selected activity coordination mechanisms in the supply chain, 2015 – The result of the work is a prepared model as well as its description in the use of Business Process Modeling Notation (BPMN). The presented model is a demonstrative model. It presents the general course of the business process, without probing into technical issues. This model allows for an understanding of the changes taking place, and also their automation in the future. This will serve future research works [6].

However, the material presented below is the result of the author's further works on activity coordination in the supply chain. The author is participating in the LOGOS entitled "Coordination model of virtual supply chains fulfilling the requirements of corporate social responsibility", intra-university program, within the framework of the first competition entitled Applied Research Program, announced by the National Centre for Research and Development. The project is being implemented by four scientific institutes: (1) The Institute of Logistics and Warehousing, (2) The Poznan University of Technology, (3) The University of Economics in Katowice, (4) The Gdansk University of Technology.

The project with the acronym LOGOS is aimed at preparing the virtual supply chain coordination model, which is to fulfil the requirements of corporate social responsibility.

The task carried out by the author entailed the elaboration of a activity coordination model, on the basis of which conducting simulation works will be possible.

The works within the framework of the task entailed:

- indication of the simulation criteria - including a definition of the objectives, key performance indicators, key decision variables as well as the scope of the simulation (borders, the border assumptions, operational assumptions),
- elaboration of selected activity coordination mechanisms in the supply chain with graphic notation help, serving to describe the business processes,
- conducting simulation experiments.

Works within the framework of the executed LOGOS project have been divided into three sub-tasks (Fig. 1):

- layer 1 - elaboration of the activity coordination models, The idea of process modeling is to construct a model, i.e., create a formal representation of a process that can subjected to a thorough analysis To perform this task, modeling languages are used. In the present work, an assumption has been made that a map of a process is its model [7]
- layer 2 - elaboration of a transport model, The majority of multiechelon systems presented in the literature usually explicitly consider the routing problem at the last level of the transportation system, while a simplified routing problem is considered at higher levels [8]. Modeling of the road in three ways shown in the article [9]. By analyzing the flow of transport should pay attention to the existence of a series of

distortions that affect the implementation of transport order. Quoting Hoffa And Pawlewskiego: “Analyzing the supply chain and, to be more exact, the transport turnaround time, it is Necessary to take into account a number of variables. The time of finishing the race depends on many factors, dry as the type of road on Which the Means of transportation is traveling, the weather conditions, driving skills, capabilities of Means of transportation and other factors.” [9]. In addition, the authors present a list of interference with a description and method of modeling.

- layer 3 - elaboration of a route model and an optimisation of the GEO routes.

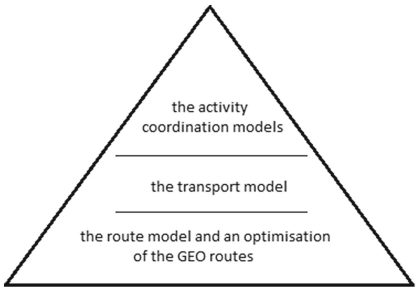

Fig. 1. The project layer sub-tasks

2 Activity Coordination - Basic Issues

The coordination and integration of activities are recommendations regarding efficient operations [10]. The coordination of activities recommends the linking of the individual system elements from the quantitative and time point of view [10]. The integration constitutes a postulate for the introduction of all and only those elements of the system that are required for it to achieve success to the » course of activities « . They should be included in such a manner so that the elements (in accordance with the meaning of the organisation) will contribute to the maximum success of the entire system [11]. Zieleniewski indicates the meaning of the coordination of events, which he understands (in a general manner) as a significant factor protecting the system against loses, which threaten the destruction of the potential organisational effect [11]. Coordination understood in such a manner is a necessary condition, although insufficient for the occurrence of this effect. Mutual information about how the implementation of the mutually intertwined system elements or that which is subject to coordination is also a necessary condition. The mutual information binds the individual parts with the help of feedback.

The research results regarding the assessment and the modelling of factors impacting the diverse cooperation and integration of the companies cooperating within the multi-agent systems (Fig. 2), conducted in Poland and Canada, indicate that sharing information and coordination are the most important [12].

Two key statements on coordination theory can be differentiated. The first of them states that coordination dependencies and mechanisms are of a general nature. This means that they can be found in various systems and organisations.

	Enablers	Mean score
1	Information sharing	4.45
2	Coordination	4.35
3	Trust	4.20
4	Willingness to collaborate	4.20
5	Communication	4.15
6	Common business goals	4.05
7	Responsibility sharing	3.90
8	Planning of supply chain activities	3.85
9	Flexibility	3.75
10	Benefit sharing	3.65
11	Joint Decision Making	3.65
12	Organizational culture	3.65
13	Organisational compatibility	3.60
14	Resource sharing (integration)	3.55
15	Top management support	3.25
16	Technological readiness	3.20
17	Training	3.10

Fig. 2. Enablers applied in the research [12]

The second statement of the coordination theory indicates that various coordination methods can be applied to the same problem. Alternative processes can occur for different coordination mechanisms. The second coordination theory statement indicates that by applying alternative coordination mechanisms, it is possible to create alternative processes.

3 Coordination of Activities in Complex Multi-agent Systems

In expanding the concept of activity coordination into the cooperation of two or more companies, the need arises for coordination at a higher level - business relations among others. Coordination presented as activity links [13] occurs between enterprises. The activity links (Fig. 3c) lead do co-dependent activities, which are synchronised and matched. The activities carried out by two (or more) enterprises in business relations become more or less interlinked due to the development of these relations. Such activities are much more efficient, as they are subject to coordination and rationalisation (they decrease the costs of performing the activities and/or increase the final result of the activity).

The coordination of activities in multi-agent systems can be related to the coordination of business activities of millions of people. Friedman claimed that there are in fact only two manners of coordinating activities.

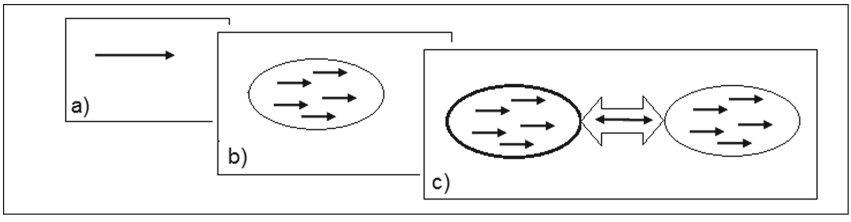

Fig. 3. Coordination (a) Individual activity, presented as an arrow, (b) Business operation, which uses five individual activities, (c) Activity links between the two enterprises; [13]

One of them is central coordination, with the "use" of a special coordination body (Fig. 4). Coordination centres are usually the leading centres. Friedman states that the central coordination must be connected with the use of coercion - just as in the military [14]. A special coordination body (lider, customer) has data sets about project. These data sets are also often complex and unstructured. Analysis of this data and acquisition of knowledge with the use of manual methods is slow, expensive, subjective, and prone to errors [15, 16].

The second manner of activity coordination is self-coordination, understood as the voluntary cooperation of units- as during an open market fair. "The possibility of coordination through voluntary cooperation is based on the fundamental truth, although often negated - that both parties to the transaction gain a benefit from it, under the condition that this is a transaction that is voluntary and conscious from both sides" [14]. One of the methods of the voluntary cooperation of entities is the Open Method of Coordination – OMC. The open method of coordination is based on:

- the mutual identification of aims to be achieved in a complex, multi-agent system,
- the joint establishment of means aimed at the achievement of goals (in the form of statistics, indicators and guidelines),
- analyses, which entail the comparison of system element activities and the exchange of good practices.

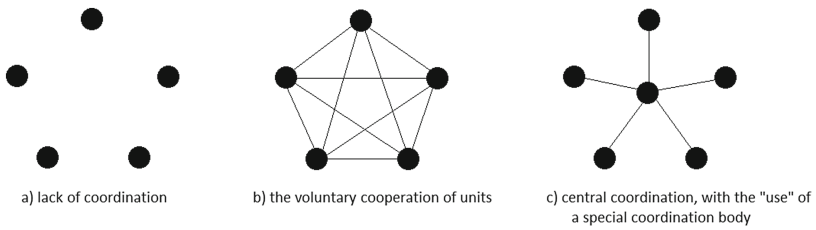

Fig. 4. Coordination forms in multi-agent systems [17]

The condition of such a "self-coordination" is either the fully unchanged repetition of the cycle of activities with the unconditional compliance with the plan known to all of the system elements, or either very succinct and fast mutual information.

There are several reasons why multiple agents need to be co-ordinated [18, 19].

- Preventing anarchy or chaos — co-ordination is necessary or desirable because, with the decentralisation in agent-based systems, anarchy can set in easily.
- Agents need to co-ordinate their behaviour if they are to meet global constraints.
- Distributed expertise, resources or information — agents may have different capabilities and specialised knowledge in a similar manner to paediatricians, neurologists and cardiologists. Alternatively, they may have different sources of information, resources, reliability levels, responsibilities, etc.
- Dependencies between agents' actions — agents' goals are frequently interdependent.

4 Selected Activity Coordination Elements - Comparison

In mechanical engineering, the mechanism can be referred to as the group of machine or device integral parts cooperating with each other, which fulfil a specific task, for example the transfer the movement. The mechanism can also be referred to as the manner of acting or the order of the events. The coordination mechanism serves to describe the manner of activities of the enterprises that cooperate with each other. A presentation of the selected mechanisms is found below.

4.1 Coordination with the Use of an Electronic Bulletin Board

The coordination mechanism with the use of the electronic bulletin board is a modified form of the classic form of coordination - contracting. Coordination with the use of an electronic bulletin board is applied when the order has a very well defined sub-order or sub-task structure. As a result, the order can be structured into its simpler sub-tasks.

The structuring of the order entails its decomposition into a series of sub-orders in order to separate the structure of the order. This is a strictly indicated system resulting from the combining of sub-orders of the entire order. Structuring enables:

- the creation of a complete overview of the entire order and its aim,
- the division of the order into smaller sub-orders, which can be given for completion to sub-contractors,
- the indication of borderline conditions for the planning, steering and supervision over the completion of the order,
- the indication of all of the resources necessary to complete the order,
- the enabling of the current review of the costs of the order,
- the establishment of the control points of the order,
- placing the efficiency gauges in order.

First variant – orderly nature.

The occurrence of two roles is visible during coordination with the use of the electronic bulletin board. The first role comes down to the ordering party, which decomposes the order into sub-orders (tasks). They also organize the allocation of these sub-orders among the cooperating counter parties, already verified as being reliable. They use their own (most often closed) database of sub-contractors as well as the so called bulletin board. The role of the subcontractor (counter party and subcontractor) is complementary to the role of the ordering party. The subcontractor carries out sub-orders directly. It can also change the role to the ordering party of a lower rank, by placing sub-sub-orders (decomposed sub-orders) in the same or different electronic bulletin board. They also use their own subcontractor database (also closed).

In analysing this variant, one can indicate the so-called distance – the distance between one cell and the remaining ones. In the presented example, Fig. 5 presents 5 enterprises (cells) and 4 channels (connections). Cells A and E are in the worst situation. They communicate directly with the sole closest cell.

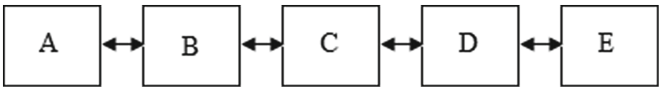

Fig. 5. Orderly nature (own work)

Second variant focused nature.

The second coordination variant with the use of the electronic bulletin board is maintaining the coordination and supervision of all of the works, even those at the lowest level of complexity, by the main ordering party. In such a case, when a sub-contractor is found for some sub-order, the scope of the works of this sub-order is decomposed into sub-sub-orders by the main sub-contractor. One can observe a repeating action (most often repeated multiple times) of the same instruction (schedule of activities) in the loop.

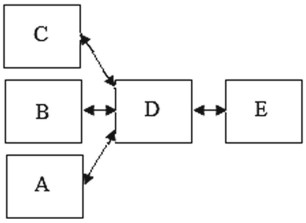

Fig. 6. Concentrated nature (own work)

In such a layout, cell D, who is the main ordering party, has the most advantageous position, having the full coordination of the activities and control over the completion of the order (Fig. 6).

4.2 Building of Structures with the Help of an Agent

It should be assumed that this is one of the simplest coordination mechanisms. It assumes that the enterprises in the built structure possess a hierarchy, previously provided. In order for it to function effectively, the execution of the following tasks is necessary:

- Initiating the creation of a database of enterprises that will operate within the structure
- Defining the scope of activities of the individual entities
- Specifying the rights and obligations of the individual entities (regulations)
- Expanding the database of enterprises through own actions (sending information through the available communication channels, i.e. e-mail, press, internet…)
- Registration of structure participants
- Approving the participants
- Agreement
- Establishing priorities and dependencies between the enterprises

The benefit of relations between enterprises defined in such a manner is the legible and explicit indication of the role that each enterprise is to play in the created structure. The building of structures with the help of an assistant most often assume the hierarchical master/slave structure. In such a case the agent master plans and sends out information on the orders to the individual subordinate agents (slave). And each of these agents transfers return information on the status of the completion of their order. The defect of such an approach is the small amount of autonomy for the slave agents. Coordination through the organisation works ideally in the coordination of the tasks of agents connected by strong hierarchical relations.

4.3 Comparison of Selected Mechanisms

Coordination with the use of an electronic bulletin board of a concentrated nature as well as the building of structures with the help of an agent are directed towards systems, in which a visible hierarchy among the partners is visible and they possess a coordinating body in the form of a main ordering party or agent (Fig. 7).

Criteria	Coordination with the use of a bulletin board		Building of structures with the help of an agent
	Orderly nature	Concentrated nature	
Manner of the coordination activities	Voluntary co-operation of the entities	With the "use" of the special coordinating body	With the "use" of the special coordinating body; agent
Hierarchy of the business partners	No	Yes	Yes
Structuring of the order	Yes	Yes	Yes
Interference in the activities of the business partner	None/small	Moderate	Strong
Cohesion of the established relationship	Loose	Moderate	Strong

Fig. 7. Criteria coordination (own work)

This body has a dominating impact on the remaining enterprises and their scope of works. They are also directed to the systems of a cohesive and well concentrated structure.

5 Conclusion

The presented activity coordination mechanism regard the problem of coordination in complex systems, which are the supply chain, at the stage of concluding trade contracts between business partners. The partners establish the terms and conditions of

their mutual cooperation within the framework of these contracts. The contracts concluded between them are at the same time the result of the market tactics, in which each party takes independent decisions. Their aim is the maximising of one's own benefits and at the same time ensuring the greatest possible efficiency of the created system.

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