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2.5 Business Process Modelling of Autonomously Controlled Production Systems

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2.5.1 Introduction

Conventional production systems are characterised by central planning and control methods, which show a wide range of weaknesses regarding flexibility and adaptability of the production system to environmental influences. Centralised planning and control methods are based on simplified premises (predictable throughput times, fix processing times of production orders etc.), which lead to an inadequate and unrealistic description of the production system. The different centralised planning steps of the traditional ERP respectively MRP based PPC-Systems are executed sequentially, therefore adaptation to changing boundary conditions (e.g. planning data) is only possible within long time intervals. This means that changes to the job shop situation cannot be considered immediately, but during next planning run at the earliest. As a result, current planning is based on old data and the needed adaptation measures cannot be performed in time for a proper reaction of the discrepancy between the planned and the current situation (Scholz-Reiter et al. 2006). In case of disturbances or fluctuating demands, centralised planning and control methods are insufficient to deal with the complexity of the comprehensive planning tasks of centralised systems, which rises disproportionately to their size and heavily constrains fault tolerance and flexibility of the overall system (Kim and Duffie 2004; Prabhu and Duffie 1995).

These weaknesses of conventional logistic planning and control systems require a fundamental reorganisation. In recent scientific research, the concept of autonomously controlled logistic systems as an innovative approach of a decentralised planning and control system is investigated, which meets the increasing requirements of flexible and efficient order processing (Freitag et al. 2004; Pfohl and Wimmer 2006). To establish the logistic concept of autonomous control adequate modelling methods are needed which allow an exact description of autonomously controlled logistic processes.

In this paper a definition of the term autonomous control in logistics and a specification of its main criteria are introduced. Based on this, the ARIS (Architecture of Integrated Information Systems) concept as an integrated method for the modelling of processes and information systems is analysed regarding its suitability to describe autonomous control in production systems. Afterwards, changes in order processing are exemplarily illustrated in several views of a business process model using the ARIS concept. The paper ends with a short summary and an outlook in respect of further research activities.

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2.5.2 Autonomous control in production systems

The idea of autonomously controlled logistic processes is to develop decentralised and heterarchical planning and control methods in contrast to existing central and hierarchical aligned planning and controlling approaches (Scholz-Reiter et al. 2006). According to the system theory, there is a shift of capabilities from the total system to its system elements (Krallmann 2004). Consequently, decision functions are transferred to autonomous logistic objects, which are defined as physical items (e.g. part, machine, conveyor) or logical items (e.g. production order) of a networked logistic system. Autonomous logistic objects have the ability to interact with other logistic objects of the considered system and are able to act independently according to their own objectives and navigate through the production network themselves (Windt et al. 2005). To achieve this, logistic objects are enabled to render decisions by themselves in a complex and dynamically changing environment by using new information and communication technologies as well as planning and control methods.

Based on the results of the work in the context of the above mentioned Collaborative Research Centre 637 "Autonomous Cooperating Logistic Processes - A Paradigm Shift and its Limitations" at the University of Bremen (Scholz-Reiter et al. 2004), autonomous control can be defined as follows: "Autonomous Control describes processes of decentralized decision-making in heterarchical structures. It presumes interacting elements in non-deterministic systems, which possess the capability and possibility to render decisions independently."(Windt and Hülsmann 2007). Based on this definition, the main constitutive criteria of autonomous control can be described as follows: heterarchical structures of the logistic system, decentralised decision-making by autonomous system elements with an own objective system, system element's ability of interaction as well as non-deterministic system behaviour (for a more comprehensive characterisation of the criteria compare Böse and Windt 2007; Windt 2006).

2.5.3 Business process modelling of autonomous control

To answer the question concerning the suitability of existing models to describe autonomously controlled logistic systems, several process studies using the ARIS concept are executed by means of existing reference models of logistic order processing (Loos 1992; Luczak et al. 1998; Scheer 1995; Schönsleben 2001). The ARIS concept as an integrated method for the modelling of processes and information systems provides several views on a system: the data view, the function view, the organisational view and the control view, which uses the EPC (Event-driven Process Chain) as modelling notation (figure 2.8).

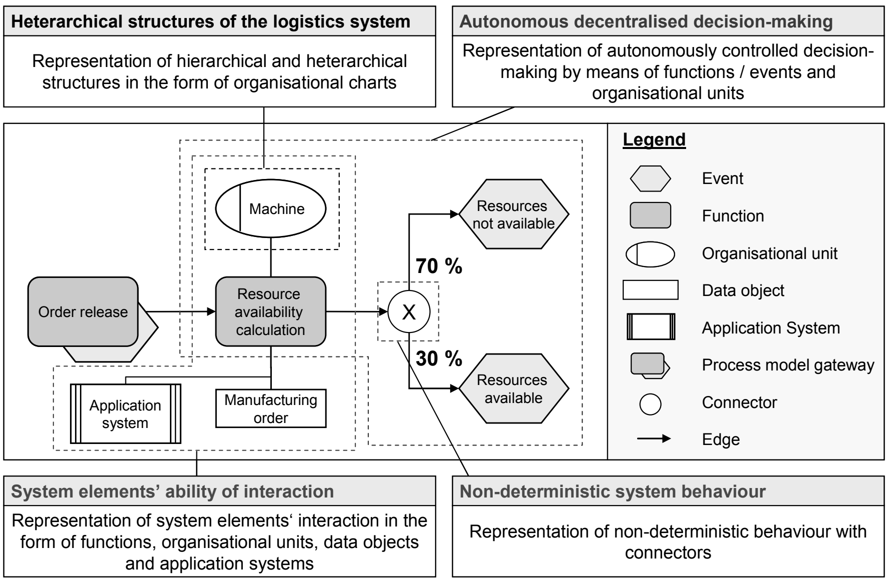

Fig. 2.8 Modelling criteria of autonomous control using EPC

A modelling method that is suited for modelling autonomous control must be able to represent the criteria of autonomous control described in the preceding chapter. Figure 2.8 illustrates the possibilities of EPC to model autonomously controlled logistic processes using as example the business process of the resource availability calculation. After order release a machine proves the availability of all needed resources to a given manufacturing order. Possible results of this function are the availability or unavailability of the necessary resources. In the given example the criteria of autonomous control can be represented as follows:

- Heterarchical structures of the logistic system: Both hierarchical and heterarchical organisational structures can be represented in the form of organisational charts. In some reference models of production systems, logistic objects (e.g. machines) are partly described as organisational units (Scheer 1995). Consequentially, in autonomously controlled logistic systems autonomous logistic objects acting as decision-making units are displayed in the form of organisational units;
- Autonomous decentralised decision-making: The criterion of decentralised and autonomously controlled decision-making executed by logistic objects can be described using several elements of EPC notation. The decision-making process is displayed by a function, the responsible decision-maker (logical as well as physical autonomous logistic objects) by an organisational unit and the possible results of decision-making by events. Various decision alternatives can be displayed in the form of different functions;
- System elements' ability of interaction: The ability of autonomous logistic objects to interact with others is represented by functions, which describe the interaction process, organisational units, which stand for the communicating logistic objects, data objects, which describe the exchanged information as well as application systems, which execute the data exchange on the software level;
- Non-deterministic system behaviour: A completely designed business process model contains all states of a considered system, which are represented by functions and events. The sequence of the functions depends on the given input, which is processed by the function to an output, and connectors, which link functions and events. Furthermore, connectors can present stochastic effects in the form of probabilities. Therefore, the specific sequence of functions and events results during run time, which leads to a non-deterministic behaviour of the considered system.

2.5.4 Changes in order processing by autonomous control

The definition of the term autonomous control in logistics and the description of its main criteria are the basis of a comprehensive investigation of the changes in order processing caused by establishing of autonomous control. Focus of interest is the question, to what extent existing models of logistic order processing are suited for modelling autonomously controlled logistic processes, respectively which modifications are necessary. The range of required modifications depends on the level of autonomous control of the considered production system. The definition of autonomous control explained in a preceding chapter describes the maximum level of imaginable autonomous control. But autonomously controlled logistic systems will probably contain both: conventionally managed and autonomously controlled elements and sub-systems.

In the following, essential modifications of existing reference models because of changes in logistic order processing due to establishing autonomous control are introduced. For this purpose the modifications in every single view of the ARIS concept are exemplarily illustrated (compare figure 2.9) and shortly described.

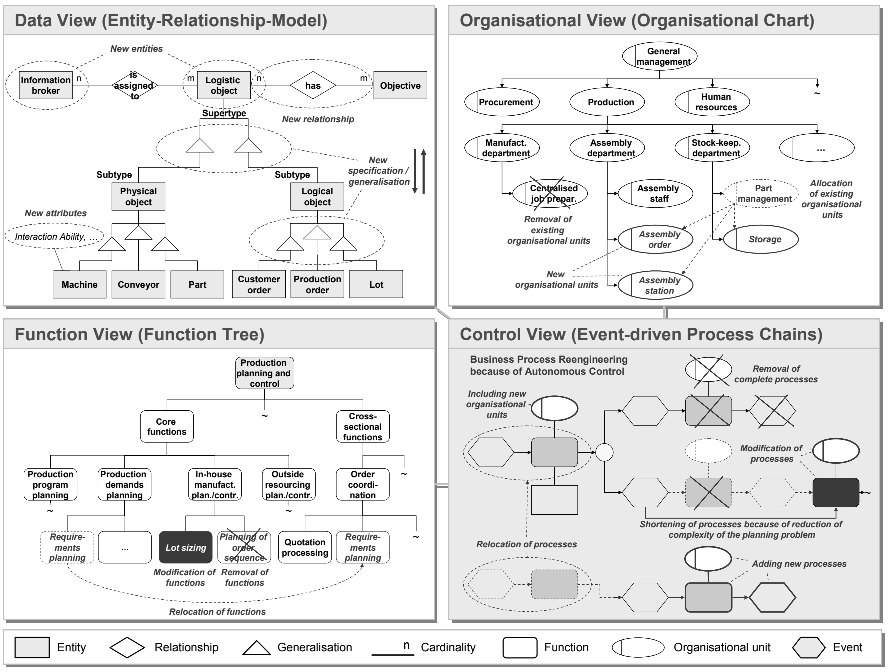

Fig. 2.9 Modelling views of autonomously controlled logistic processes

Data view

Existing data models, for example in the form of an ERM (Entity-Relationship-Model), are not sufficient to adequately describe entities in autonomously controlled logistic systems, but have to be extended by new entities, attributes, relationships as well as specification / generalisations (figure 2.10). As described in a preceding chapter, in autonomously controlled systems autonomous logistic objects, both physical and logical objects, have the ability to interact with other logistic objects of the considered system, to act independently according to their own objectives and navigate them through the production network. Considering these criteria of autonomously controlled logistic systems, the logistic object as well as the physical and logical object has to be added as new entities just as the belonging generalisation between these new entities. Furthermore, there is a new relationship from the entity objective to the new entity logistic object. A new entity information broker is introduced to represent special information broker objects. These objects are needed in autonomously controlled systems to register the logistic objects at certain process stations and provide communication links between them. Also, the interaction ability has to be added as an attribute of an entity, for example as attribute of the entity machine. Accordingly, the complexity of data models of autonomously controlled systems rises due to the addition of new entities, attributes, relationships as well as specifications / generalisations.

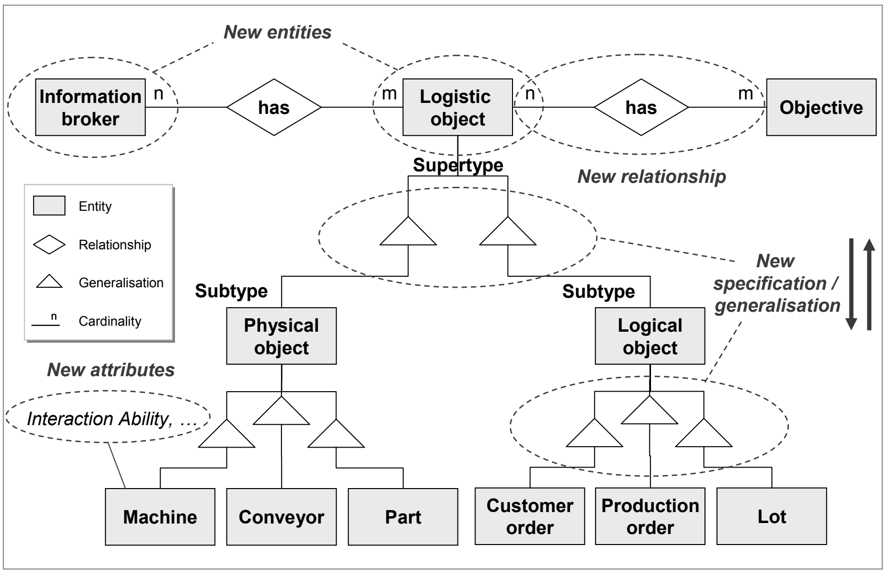

Fig. 2.10 Data view of an autonomously controlled logistic system

Function view

The modifications of the function models, pictured in the form of a function tree (figure 2.11), are determined by the decentralisation of the planning and control functions to the logistic objects, that requires a relocation respectively reorganisation of several functions. For example, in autonomously controlled logistic systems there is no longer a centralised requirements planning. Instead, this function is moved from the centralised system to the logistic object order and with it assigned to the superior function order coordination. Some functions of conventional planning and control systems, which are executed centralised for several logistic objects, are removed. For instance, the function planning of order sequence in the field of in-house manufacturing and control is no longer needed because the control of order sequence happens at run time by the machines themselves. Other functions still remain, but require an alteration. For example the activities within the function lot sizing is simplified due to the fact that based on the decentralisation of the planning and control functions there is no longer a centralised lot sizing, but a local lot sizing coordinated by a single machine.

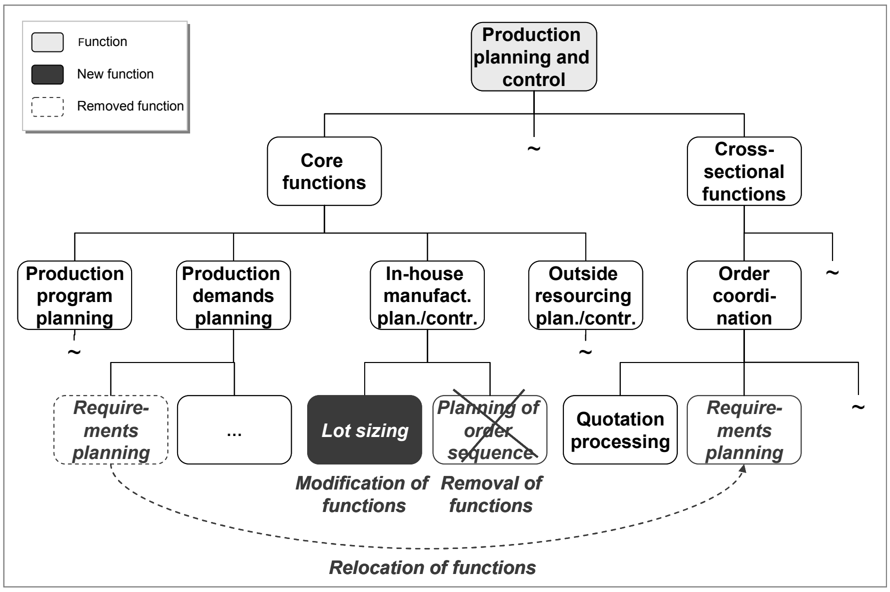

Fig. 2.11 Function view of an autonomously controlled logistic system

Organisational view

There are several changes concerning the organisational structure caused by establishing autonomous control in order processing due to the fact that in autonomously controlled systems logistic objects are able to initiate and execute functions (figure 2.12). Because of the relocation of functions to the logistic objects some centralized organisational units are no longer needed, for example the organisational unit centralised job preparation. Some organisational units are substituted by other, partly new organisational units. So the organisational unit part management is replaced by several logistic objects such as storage, assembly order and assembly station, which are added as new organisational units. Thus a logistic object can function both as an entity and organisational unit. Even though in autonomously controlled logistic systems logistic objects are able to initiate and execute functions within order processing, it is highly doubtful, whether they can take on a responsibility for the related functions or their results. On the contrary, it makes sense, that not the single logistic object but rather the superior "human" organisational unit is responsible for the results and (unintended) effects of the functions.

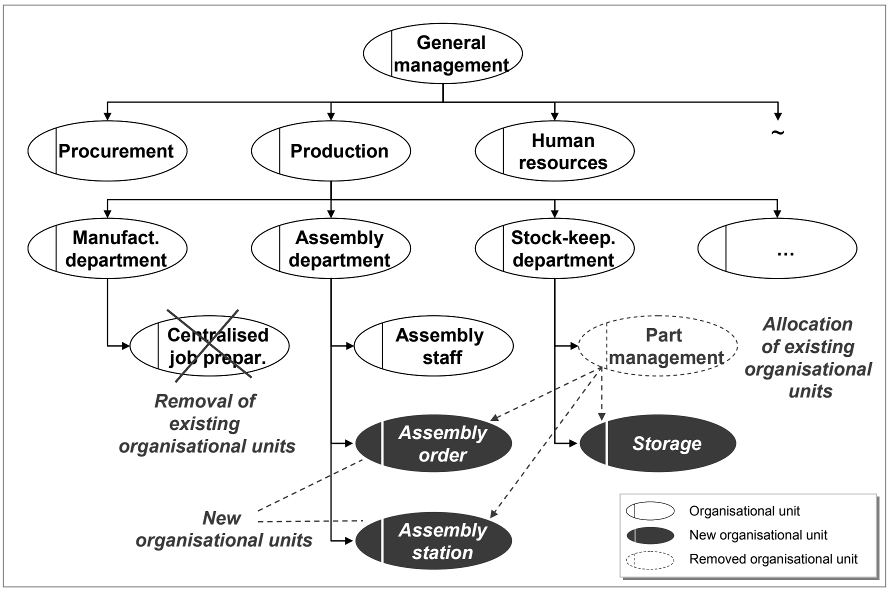

Fig. 2.12 Organisational view of an autonomously controlled logistic system

Control view

The modifications of the data, function and organisational view are reflected in the control view, which contains the adaptations of the business processes of the planning and control system caused by establishing autonomous control. The wide range of manifold modifications of the several views results in a corresponding number of modifications in the control view. In the context of this paper, only a common illustration of the changes is introduced (figure 2.13). As described above, new organisational units as well as new entities have to be included because of the existence of autonomous logistic objects. The decentralisation of planning and control functions to the logistic objects causes relocations of processes within the work flow, removals of complete processes as well as shortenings and modifications (modifications of functions, replacing organisational units, adding new entities etc.) of logistic processes. This results in two different effects on the complexity of the business process model. The decentralisation of the planning and control tasks reduces the need for long and complicated process chains of planning and control tasks. However, it also results in an increasing number of (redundant) processes and thus leads to a higher complexity of the business process model.

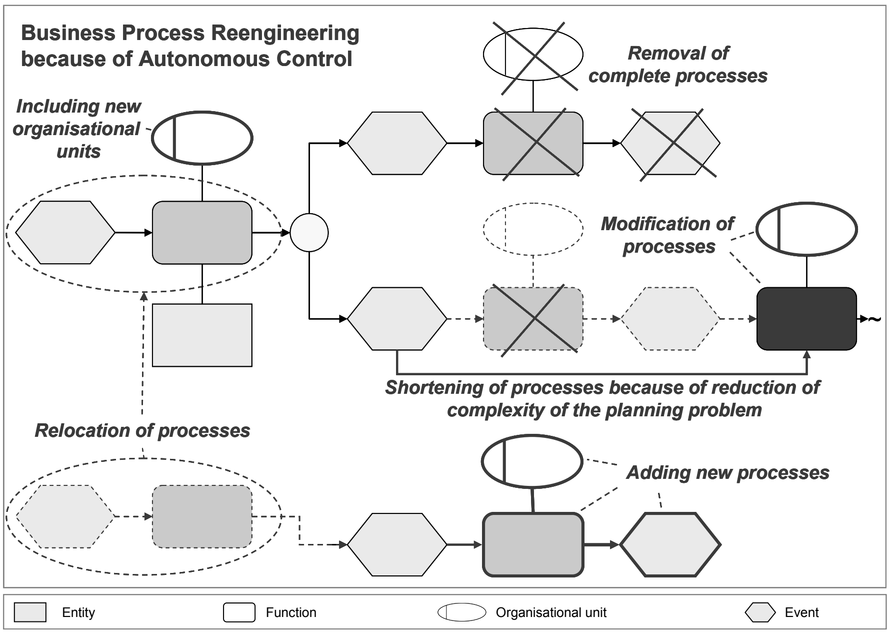

Fig. 2.13 Control view of an autonomously controlled logistic system

2.5.5 Conclusions

In the context of this paper the concept of autonomously controlled logistic systems was introduced as an innovative approach of a decentralised planning and control system, which meets the new requirements of flexible and efficient order processing. Based on the definition of the term autonomous control within the scope of logistics and the constitutive criteria, the ARIS concept was analysed regarding its suitability to describe autonomous control in production systems. Furthermore, it has been shown, that there are several changes in order processing of production systems caused by establishing autonomous control, which are not sufficiently considered in existing models of logistic order processing. Manifold modifications of existing models are necessary, which depend on the level of autonomous control of the considered production system. Using the ARIS concept, several modifications were introduced regarding data, function, organisational and control view. Future research is focused on the detailed investigation and modelling of changes in logistic order processing by establishing autonomous control. Main objective is the development of a reference model of the autonomously controlled logistic order processing using the example of a job shop manufacturing scenario.

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