Analysis of the possibility of SysML and BPMN application in formal data acquisition system description

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Abstract. The article presents the study of possible application of selected methods of complex description, that can be used as a support of the Manufacturing Information Acquisition System (MIAS) methodology, describing how to design a data acquisition system, allowing for collecting and processing real-time data on the functioning of a production system, necessary for management of a company. MIAS can allow conversion into Cyber-Physical Production System. MIAS is gathering and pre-processing data on the state of production system, including e.g. realisation of production orders, state of machines, materials and human resources. Systematised approach and model-based development is proposed for improving the quality of the design of MIAS methodology-based complex systems supporting data acquisition in various types of companies. Graphical specification can be the baseline for any model-based development in specified areas. The possibility of application of SysML and BPMN, both being UML-based languages, representing different approaches to modelling of requirements, architecture and implementation of the data acquisition system, as a tools supporting description of required features of MIAS, were considered.

1. Introduction

The need of continuous improvement forces companies competing on the global market to actively search for new solutions allowing to gain an advantage over competitors. Improving of the company operation can be based on advances in hardware, mainly introducing automation [1] and robotics [2] into production processes, as well as on organisation operation [3], design and management optimisation [4], based on simulation [5][6], scheduling [7][8], and other modern technologies [9][10].

Nowadays, when IT systems supporting company management in many areas are becoming increasingly complex, traditional non-formalised document-based methods of system development are not reliable and efficient enough to develop well thought-out and organised systems incorporating organisational, hardware and software solutions (Cyber-Physical Production Systems). A system supporting acquisition of data on the state of a production system is an example of a system placed below other IT systems and supplying real-time information that will be processed in ERP (Enterprise Resources Planning), MES (Manufacturing Execution Systems) and other IT systems [11]. Development of this kind of system can be based on the MIAS (Manufacturing Information Acquisition System) methodology, proposed in prior publications [12]. The proposed MIAS methodology is both multi-stage and multi-level, dividing development of data acquisition system into three main stages (analysis of various aspects of the company in which MIAS is applied, synthesis of
technical and organisational solutions, and evaluation of the proposed solutions) on four levels of analysis (levels of company as a system, data sources, data pre-processing, and communication). MIAS methodology can be regarded as a tool allowing integration and conversion of classical production system into Cyber-Physical Production System (CPPS), proposed as a part of Industry 4.0 strategic initiative [13].

Model-based development is the proposed direction for future work on the design of complex systems supporting data acquisition in various types of companies. Graphical specification can be the baseline for any model-based development in specified areas [14].

The paper presents attempt to use of two different (SysML and BPMN) UML-based languages and approaches for description of requirements, allowing of systematised development of architecture and implementation of data acquisition system according to MIAS methodology.

The first tool, Business Process Model and Notation (BPMN) is intended to provide businesses with the capability of understanding internal business procedures in a graphical notation and give organizations the ability to communicate these procedures in a standard manner [15]. Furthermore, the graphical notation should facilitate the understanding of the performance, collaboration and business transactions between entities in the organization.

The second, OMG Systems Modelling Language (OMG SysML) is a general-purpose graphical modelling language meant for specifying, analyzing, designing, and verifying complex systems, including hardware, software, information, personnel, procedures, and facilities [16]. SysML provides graphical representations with a semantic foundation for modelling system requirements, behaviour, structure, and parameters, which can be used to integrate with other engineering analysis models. Available types of diagrams allow for the description of data acquisition system structure, behaviour, requirements, parameters and relationships [17].

2. Cyber-Physical Systems and Cyber-Physical Production Systems

Cyber-Physical Systems (CPS) can be defined as systems consisting of collaborating computational entities which are constantly connected with its physical surrounding and its ongoing processes. CPS are at the same time providing and using data, available in local and Internet services [18].

According to [19], a modern cyber-physical system is a heterogeneous technical system consisting of a network of potentially diverse physical, software-controlled components. A general rule of this category of systems is that such a system should be designed as a whole. When decomposing CPS into subsystems, it is necessary to constantly evaluate and, if necessary, adjust the relationships between the parts and the whole system. This is a different approach from the traditional, where divided, separate subsystems are designed. That change is forced by the growing functional complexity of contemporary technological systems, which are nowadays much more integrated functionally than before. In result, the design of the parts and the global system have to be interconnected.

In manufacturing environment the concept of CPS can be expanded into Cyber-Physical Production Systems (CPPS). CPPS relying on the developments of computer science (CS), information and communication technologies (ITC), and manufacturing science and technology (MST), may lead to the 4th Industrial Revolution (noted as Industrie 4.0 or Industry 4.0), promoted by Germany's Federal Ministry of Education and Research [19]. The Industry's 4.0 main features are: strong individualization of products under the conditions of large series but at the same time highly flexible production, the extensive integration of customers and business partners in business and value-added processes, and the linking of production and high-quality services leading to so-called hybrid products [20]. Industry 4.0 goal is to get more efficient and flexible production systems, at the same time reducing times and costs of product development and whole lifecycle.

CPPS consist of autonomous and cooperative elements and sub-systems that are getting into connection with each other in situation dependent ways, on and across all levels of production, from processes through machines up to production and logistics networks. When designing CPPS it is necessary to take into account, i.a. operating sensor networks, handling big amounts of data, as well as information retrieval, representation, and interpretation, at the same time ensuring information security.
The proposed Manufacturing Information Acquisition Systems methodology can be an important part of CPPS and Industry 4.0 concepts, allowing for the development of subsystems responsible for collecting, transmitting and pre-processing data from all manufacturing activities. CPPS is meant for newly designed production systems, while MIAS could provide technical and organisational means for horizontal and vertical integration throughout production systems, allowing modernisation of existing production systems into CPPS.

3. Model-based Systems Design (MBSD) / Model-based Systems Engineering (MBSE)

Model-based Systems Design (MBSD) or Model-based Systems Engineering (MBSE) are proposed as an alternative to Document-based Systems Engineering Approach, in which specifications for a particular system, its subsystems, and its components are usually presented in a form of hierarchical tree (specification tree) [21]. MBSE is typically based on the concept of documents defining how the system will support the required objective. In order to decompose the system functions and allocate them to the components, functional analysis is performed. Functional analysis can be supported by drawing tools, such as functional flow diagrams and schematic block diagrams. These diagrams are included in the system design documentation and stored as separate files. Analyses are performed and documented in many areas to allocate performance requirements and evaluate alternative designs. Tracing requirements between the specifications at different levels of the hierarchy allows to perform requirements traceability. The document-based approach has some limitations, e.g. it is difficult to assess the completeness, consistency, and relationships between requirements, because the information is spread across many separate documents. Another disadvantage is the fact, that document-based system design is difficult to maintain, also reusing the system requirements and design information for an evolving or variant system design is difficult [21].

The other proposed method, Model-based Systems Engineering/Design (MBSE/D) applies systems modelling as part of all stages of system design. A model is a representation of concept (or more concepts) that may be realized in the physical world. “Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later lifecycle phases” [21]. The effect of the MBSE is a coherent model of the system. MBSE allows for the reuse of system specifications and other elements, enhances quality of specification and design, and improves communications between members of the development team.

The system model is usually created using a modelling tool and stored in a model repository. It contains system specifications, design, analysis, and verification information. The model consists of model elements representing requirements, design, test results, design rules, as well as their relationships.

The list of currently existing modelling notations contains, i.a.: Function Blocks (IEC 61499), Function Block Diagram (IEC 61131), Petri nets, Swimline Diagrams, UML 2.x, SysML, and BPMN. It was decided to focus on potentially MBSE-compatible methods for describing complex relationships and extended systems, for which ready-made development packages are available - UML, SysML and BPMN.

The Unified Modeling Language (UML) was established as a widely accepted standard in software engineering, but it is not fully fit to other disciplines, because it has overly software-oriented semantics. UML is not appropriate for complex cyber-physical systems design because it does not allow a clear expression of physical flows passing between the systems components. Also managing some system aspects needed proper stereotypes to be developed [18].

Disadvantages of the UML forced the OMG (Object Management Group) to propose in 2007 a new profile focused on system engineering, the SysML (OMG Systems Modeling Language) [16]. SysML is a subset of UML, based on the UML2.0 specification and on other engineering graphical representations, such as Enhanced Functional Flow Block Diagram (EFFBD), adding required modelling possibilities specific for wider range of systems modelling [22]. SysML is a general purpose language based on UML, that is less software-specific to achieve a wider acceptance [23].
based on a set of modelling elements grouped in different diagrams, allowing to support complex system models. It facilitates the description of both, system structure and behaviour, taking into account design requirements [24].

The other description method considered, is the Business Process Model and Notation (OMG BPMN), that is seen as a standard for business process modelling, providing graphical notation for specifying business processes in a Business Process Diagram (BPD), based on traditional flowcharting techniques [15]. The BPMN purpose is to support business process modelling for both technical and business users, by providing notation intuitive to business users, but is still able to representing complex processes semantics. In the BPMN 2.0 version, it also provides execution semantics and mapping between the BPMN graphics notation and other execution languages, e.g. BPEL (Business Process Execution Language). BPMN is designed to be understandable for business analysts (responsible for identifying processes), technical developers (responsible for implementation of IT systems), as well as business managers. BPMN can be considered a common language, able to cover the gap frequently occurring in communication between business process design and software implementation [25].

3.1. SysML
OMG SysML is an extension of UML, purposed for systems engineering modelling. It provides designer with 9 types of diagrams (requirement diagram, activity diagram, sequence diagram, state machine diagram, use case diagram, block definition diagram, internal block diagram, parametric diagram, and package diagram), allowing formalisation of system requirements, behaviour, structure, and parametric constraints, giving the possibility to view a system, being designed or described, from different perspectives [26]. The main aspects of modelling Manufacturing Information Acquisition System include the structure, requirements and behaviour modelling.

3.1.1. Structure modelling. The main tool for structure modelling is Block Definition Diagram, representing structural elements (blocks) with their properties, relationships and composition. The interfaces and connections between parts of a block can be represented in Internal Block Diagram (a modification of the UML’s composite structure diagram), while Parametric Diagram represents parameters relationships and constraints on property values. Next diagram, a Parametric diagram can be used to identify the main system parameters and their relationships seen as constraints, that are convenient to be exported to other simulation tools. Package Diagram displays the packages containing elements being modelled [22].

3.1.2. Requirements modelling. Requirements modelling includes requirement capture and analysis (including defining critical requirements and balancing conflicting requirements etc.), as well as requirements final allocation (to use cases, test cases, components, etc.). Requirement diagram allows for the capturing, analyzing and maintaining traceability of requirements in the modelled system. A correct representation and allocation of requirements to corresponding parts of the system are necessary to allow the validation of final model. In case of vast, heterogeneous systems, requirements can also be organised in tables or matrices, describing the desired relationships and properties, concerning different model elements. Specifying test cases and linking them to the corresponding requirements, showing methods of requirements verification, is also possible [22].

3.1.3. Behaviour modelling. Different kinds of behaviour can be modelled thanks to availability of different SysML diagrams, allowing for complete specification of a system [22].

- **A flow-based behaviour** is described in the terms of the flow of outputs, inputs, and control. An Activity diagram represents a sequence of actions transforming inputs onto outputs. It describes functional architecture of a system and specifies the functions to be performed by the system, as well as their hierarchical breakdown, showing distribution of the flow.
- **An event-based behaviour** is meant to express the response of entities to events (internal and external). State machine diagrams can be used to identify different states of a system. This type of diagrams allows for the definition of the transition from one system state to another. Every case is treated individually, and as a consequence, comprehensive description of the system behaviour is obtained.
- Use cases can represent **functionality of a system**, describing services it provides to its users. Use Case Diagram can show how a system is used by external entities (different types of users).
- **Message-based behaviour** approach can be used in modelling of service-oriented systems. It is supported by Sequence diagrams, representing interactions either between system and its environment or between different components of system at various levels of hierarchy of a system.

3.2. **BPMN**

Business Process Management (BPM) is still gaining importance because many companies noticed the significance of identifying and documenting their business processes. BPM allows for introducing key performance indicators (KPIs) intended for measuring and monitoring process performance, as well as implementing continuous process improvement and innovation systems. BPM and its graphical representation simplifies the implementation of IT systems, supporting company management (monitoring, processes control software, MES or ERP), and corporate culture development [27].

OMG Business Process Model and Notation (BPMN) is becoming the standard in processes modelling, because it is based on a simple, similar to flowchart diagrams, graphical description, standardised (ISO/IEC 19510:2013), and can support execution processes. It allows for analysing of sophisticated models, including event handling and messaging, that is important in the area of Business Process Management [28]. There are both, commercial and open-source BPMS (Business Process Management Suites) software tools, available, compared and described in [29].

BPMN defines the notation and semantics of collaboration diagrams, choreography diagrams, and process diagrams. It provides means of relying and explaining process information to business users, process implementers, suppliers and customers [25]. The BPMN notation offers a set of basic shapes, grouped into categories, including task description (no task, user task, manual task, service task, receive task, send task, script task, business rule task, sub-process and a call activity), flow description (sequence flow, message flow, association, and data association), marker description (loop marker, parallel multi-instance marker, sequential multi-instance marker, ad-hoc marker, and annotation marker), data objects description (data object, data input, data output, data store, and a collection of data objects), event description (start events, non-interrupting start events, intermediate events, non-interrupting boundary events, end events, receive and send messages, timer event, escalation event, link event, catch event, throw event, cancel events, conditional events, compensation event, catching and throwing signal events, multiple event, parallel multiple event, and terminate end event), and gateway description (event gateway, inclusive gateway, parallel gateway, event-based gateway, and parallel event-based gateway).

BPMN diagrams are used to describe a variety of process configurations to different clients. There are 3 basic types of sub-models available in a BPMN modelling environment: Processes/Orchestration (private non-executable internal Business Processes, private executable internal Business Processes, and public processes), Choreographies, and Collaborations, which can include Processes and/or Choreographies (a view of Conversations) [25].

- Private Processes (Orchestration) sub-models represent workflow of processes that can be executed according to defined semantics (private executable internal Business Processes) or private non-executable internal Business Processes (modelled for documenting Process behaviour without information needed for execution, such as formal condition expressions). A public Process shows the interactions to and from another Process or Participant, it contains only Activities and Events used to communicate with the other Participants.
• A Collaboration sub-models represent the interactions between two or more objects. They usually contain at least 2 Pools (representing the Participants in the Collaboration). The Message exchange between the Participants is shown by Messages connecting Pools (or the objects within the Pools). The Messages can be represented graphically. A Collaboration diagram can be informally extended by the Conversation diagram, representing the logical relation of Message exchanges.

• A Choreography sub-model is a definition of the expected behaviour meaning a procedural contact between Participants. Contrary to a normal Process, that exists within a Pool, a Choreography happens between Pools (or Participants). It is functionally similar to a private Business Process because it a set of a network of Activities, Events, and Gateways.

4. Manufacturing Information Acquisition System

Knowledge about the current state of manufacturing processes is important for management of any company. Company management, that is usually supported with ERP system, is only possible when ERP is continuously fed with data on the current state of production processes. In many companies there is no direct communication between the management and production areas - there are no mechanisms allowing automatic transfer of information from the production system, communication is significantly delayed, or do not provide all the required data [30].

The proposed Manufacturing Information Acquisition System (MIAS), supplying the data to IT systems and the company managers, can be designed based on the MIAS methodology [31]. A customised data acquisition system constitutes a link between data sources, MES/ERP systems and company management.

4.1. What is Manufacturing Information Acquisition System

In order to maintain expected functions, Manufacturing Information Acquisition System should include data sources in both automated (PLC, CNC, SCADA, sensors, etc.) and non-automated (data collectors, RFID, barcodes, etc.) production systems, modules allowing for the pre-processing, integration, archiving and sharing of the collected information, as well as communication interfaces. MIAS should be able to collect data on execution of production orders, operation of machines, tasks performed by workers, location and flow of objects (materials, WIP, products, equipment) from multiple data sources through standardised interfaces. The data obtained should be pre-processed (reduced, aggregated, and compressed) in order to avoid information flood, and then archived. Aggregation means that data on states of single variables should be interpreted and converted into synthetic process variables, calculated based on the state of many sensors/devices. All data collected by MIAS (current and historical) should be available to multiple clients, either massive IT systems, supporting company management (MES, ERP), or on-line reports, charts, ANDON or dashboards, useful for process operators, shift leaders and mid-level managers [32].

MIAS should by designed in the way, allowing acquisition of data on activities and states of processes in both, automated and non-automated parts of production system. Bi-directional communication in MIAS should provide ability to send commands (e.g. production orders, corrective actions, individual tasks assigned to workers) from the management to selected sources of data, allowing relying commands from higher-level systems.

In order to obtain reliable, complete Manufacturing Information Acquisition System for any given company, a systematised design methodology (MIAS methodology) should be applied.

4.2. Typical system engineering processes

Cyber-physical systems are multi-disciplinary and contain subsystems or components from different disciplines interacting together. Their design aims at satisfying system-level requirements/functionalities. The old method of dividing design into separate disciplines should not be directly used for complex cyber-physical systems design, where specialists from interdependent
disciplines are collaborating simultaneously on a system-level model to understand the whole behaviour of the system and the dependencies between different areas of expertise [22]. The way of designing complex engineering systems is multi-stage, because every system can be different, although there are common stages and elements, that can be reused. Generally, all projects require the definition and understanding of requirements, generation of alternatives, and analysis of devised solutions. All these steps are divided into elementary tasks and repeated, until result is satisfactory (Figure 1) [23].

![Figure 1. System engineering workflow [23].](image)

In order to provide a balanced solution addressing the diverse (sometimes even conflicting) needs, the System Specification and Design process (Figure 2) should include the following activities [21]:

- Identify and analyze the future user needs in order to understand the problem to be solved, the goals the system should support, as well as the effectiveness measures allowing to evaluate how well the system supports goals and satisfies the user's needs.
- Specify the requirements concerning system functionality, interfaces, physical and performance characteristics, and other quality characteristics to provide the goals and effectiveness measures.
- Synthesize a set of alternative system solutions by dividing the system design into smaller components, satisfying the specified requirements.
- Perform analysis in order to evaluate solutions and select a preferred one, satisfying the requirements and maximising the proposed effectiveness measures.
- Check compatibility of devised solution with the system goals and components requirements in order to check if primary user needs can be satisfied.

![Figure 2. Simplified systems engineering technical processes [21].](image)
4.3. The MIAS methodology

The data acquisition system for a specific company should meet various requirements, that stems from the characteristics of the organization for which it is designed. Due to the complexity, MIAS should be created in a multi-stage and multi-level process. The starting point for designing of MIAS is the primary need, formulated by the stakeholders of a company, in which the system will be applied. The designing process should be carried out in three stages, on four proposed levels of analysis [31].

The main proposed stages of MIAS development (presented in Figure 3) are as follows:

- **stage 1** – analysis and identification of organizational and technical structure of the company, problems with data acquisition and other features of the company,
- **stage 2** – synthesis of technical and organizational solutions of MIAS,
- **stage 3** – evaluation/verification/assessment of proposed solutions.

There are four levels of analysis proposed in the development of MIAS for specific user:

- **level 1** – level of company as a system,
- **level 2** – level of data sources,
- **level 3** – level of data processing,
- **level 4** – level of communication.

The analysis of requirements and existing capabilities (1-st stage) should be carried out for each level, whose results should allow for the formulation of the specific requirements for MIAS at a given level.

After completing the analysis at all four levels, the synthesis stage (2-nd stage) can be carried out. In the 2-nd stage design solutions of MIAS elements are proposed, based on the requirements identified in 1-st stage. Finally, the 3-rd, evaluation stage takes place, in which specific MIAS project is verified at different levels in terms of fulfilling requirements and objectives, formulated in the 1-st stage. As a result of verification, specific parts of the project could be returned to the 2-nd stage for

**Figure 3. MIAS methodology scheme.**
development of alternative solutions. The verification is repeated until devised solutions on all detail levels are satisfactory.

Analysis and mapping of the structure of the company, including links between functional components and processes should be the base of MIAS development. The result of the mapping should be an image of the structure and processes, stored in one of the business process modelling standards.

The variability of production processes in the company is one of important elements that should be taken into account when designing MIAS. Companies running stabilised, mass or large-series production processes without much configuration changes are easier subjects when designing MIAS, contrary to producers leading high-variability (e.g. short series, the need of time to set-up machines, routes of technological processes, etc. can be highly-variable), being much more difficult subject of complex data acquisition.

4.4. Requirements concerning tools supporting MIAS methodology
Implementing the MIAS methodology requires tools supporting the design process on analysis, synthesis and evaluation stages. An expert system (The MIAS Advisor [33]) has been already developed, based on the Exsys Corvid environment, to support a part of synthesis stage - the selection of data sources for specific applications. It can be easily extended to cover other aspects of MIAS synthesis stage. This is an important part of MIAS design, however there is still a need to develop a tool to help the entire design process, formalizing the steps proposed in the MIAS methodology. The proposed tool can be a UML, SysML, or BPMN diagram template that contains predefined, common elements, structures, and relationships that will help fill the relevant fields in the MIAS structure responsible for the various tasks. The template should include the new predefined objects and functions needed when modeling the specific tasks and requirements of the production data acquisition system. Modeling different types of objects at different levels of the hierarchy as well as the relationships between these objects should be possible. The template should provide the ability to formulate requirements and expectations for objects that may later be used as criteria for evaluating developed solutions. Tracking and determining the degree of compatibility of developed solutions with accepted requirements are also expected.

The following points outline the main issues that should be taken into account when designing a tool (such as a template set) that supports MIAS analysis at given levels.

4.4.1. Level 1 analysis - company as a system. This level of analysis is focused on discovering the primary need, that caused interest in the implementation, as well as company's structure and signals from surrounding, economic and natural environment.

- Identification of the primary need for data acquisition system - allows the definition of its role and place in the company.
- Discovering, analysis and description of the company's organisational structure - it should allow the obtaining of a list of information that should be acquired from the production system, including connections between main entities.
- Analysis of the currently used IT systems - it should cover IT systems used in a company, supporting different areas of its operation. This part of analysis should determine information needs and available information exchange formats, as well as a list of data, that can be acquired from specific IT systems (especially those operating in the production system).
- Identification of common problems in functioning of the production system - problems appearing periodically or irregularly should be identified, based on the experience of employees and history of production system exploitation. Types of problems and its characteristics (including the circumstances, place of occurrence, and reliance on other events) should be discovered and described.
- Analysis of the need for use of the MIAS interfaces to transmit downstream commands, instructions and orders (control channel).
4.4.2. Level 2 analysis - data sources. Data sources, included in MIAS should be able to provide information specified on 1-st level of analysis. Set of analysis, examining existing and required data sources, should include the following points.

- Analyse of existing data sources and the possibility of its reuse in the MIAS - existing data sources, both automatic and manual, should be identified and described, including assessment of usability in MIAS.
- Determination of the possibility of including IT systems cooperating directly with the business layer into MIAS – allows future including of separate IT or control systems in MIAS.
- Identification of the needs for creation of new data sources - based on a list of already available data sources and information needs identified on level 1.
- Identification of specific restrictions and conditions - determination of potential technological limitations, related to specific conditions (e.g. risk of explosion, high humidity, pollution, dust, aggressive chemicals, extreme temperatures), in which data acquisition system has to operate.

4.4.3. Level 3 analysis - data processing. MIAS should deliver data to the higher layers IT systems, where advanced processing is carried out, but the data, mass-produced e.g. in control systems, should be pre-processed and initially-interpreted, preventing data flood of higher level IT systems. At the data processing level, the requirements for integration and archiving of data in the MIAS are considered.

- Analysis of relations between the data available and required information - allows the identification of data processing needs. This allows the integration and combining of basic data into a larger, hierarchical structure, providing pre-processed information on the state of production system.
- Discovering the need of data interpretation algorithms.
- Analysis of requirements and capabilities of local processing, archiving and sharing of information - covers possibility of local data processing, distribution of data aggregation and interpretation procedures, as well as storage, between dispersed data processing and archiving servers.

4.4.4. Level 4 analysis - communication. This part of analysis includes questions related to ensuring reliable communication and interfaces between MIAS components in given environment. It should include hardware and software aspects of connections between MIAS elements, as well as protocols, common data formats, and issues of information security.

- Analyse of potential physical communication links between MIAS components, including projected new data sources and local pre-processing centres.
- Analyse of common protocols and data exchange formats, both, available in existing systems, and modern popular standards.
- Discovery of restrictions depending on the local law or hazardous/harsh environmental conditions.

5. Conclusion and further research directions
Creating a system-level Manufacturing Information Acquisition System model, in a unified unambiguous language, can be a key point for a successful implementation of MIAS methodology. The system-level model can be the reference to which each system designer should refer, providing unique set of data that is shared by every member of development team. Thanks to existence of common model, everybody can easily find the information needed. In the case of MIAS multi-view model, multi-level model template, with different representations of the system, is necessary. These
different views and levels should be linked together with traceability links and be consistent with each other.

Because of the wide range, complexity, and variety of issues that must be represented in the MIAS description, it is imperative to use tools that enable a comprehensive representation of the different aspects of the system, its structure, its interconnections and requirements. An analysis of the needs and capabilities provided by BPMN and SysML indicates that the best solution would be to use the mechanisms provided by both modeling notations/languages to provide a comprehensive and complete description of the MIAS system being designed.

BPMN is better solution for description of initial overall system structure, because it is based on a simple graphical description, allowing for creating of sophisticated models, including event handling and messaging. BPMN allows for the notation and description of semantics in collaboration, choreography, and process diagrams. The BPMN notation offers a set of basic shapes, grouped into categories, including task description, flow description, marker description, data objects description, event description, and gateway description. BPMN provides means of relying and explaining process information to all potential members of development team: stakeholders, managers, production system engineers, workers and operators, system architects, process implementers, hardware and software developers. BPMN diagrams can be used to describe a variety of process configurations to different clients. BPMN however, does not provide tools to describe e.g. requirements and other aspects of MIAS with enough detail and accuracy.

UML, as a tool designed to meet the needs of software development, is supported by many commercial and open source tools, and is relatively well known in the engineering community. Therefore, it was used as a base for SysML, offering much wider set of cyber-physical systems description tools. OMG SysML provides system engineer with nine specific types of diagrams (requirements, activity, sequence, state machine, use case, block definition, internal block, parametric, and package diagrams), allowing for formalising system requirements, structure, behaviour, and parametric constraints. SysML gives the MIAS system designer the ability to view a system being designed from different perspectives. The main aspects of modelling MIAS include structure, requirements and behaviour modelling, on all four levels of analysis, and subsequent verification of developed solutions in the aspect of fulfilling requirements and offering expected functionality for acceptable cost and effort.

The results of the analysis will be used for further work including the development of model and diagram templates, describing the various aspects of MIAS, including the structure of the enterprise and the production system, data sources, objects producing, processing and consuming data, as well as requirements concerning the co-operation between these objects. Also new objects that allow for the description of MIAS-specific issues in BPMN and SysML environments must be developed.

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