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# Business Process Modelling Languages

František Kožíšek, Ivan Vrana

Faculty of Economics and Management, Czech University of Life Sciences Prague, Czech Republic

## Abstract

This paper summarizes the current knowledge of business process modelling languages, which is increasingly important also in the agri-food industry. It describes the history of business process modelling, currently mostly used alternatives – UML, BPMN, EPC and recaps their strengths and features in which they outperform the others. As demonstrated all three notations can adequately model business processes. They do however differ in some specific features. In some aspects, each of the languages always outperforms the others. Important is that except of some general objective features where the languages differ, there is also a lot of subjective perception of how the single notations perform.

## Keywords

Business Process Modelling, UML, BPMN, EPC.

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## Introduction

Business process management (BPM) is an important topic for any organization nowadays. For each business goal, an organization has a set of activities, which must be undertaken. Business Processes are then a way to organize these activities and understand their interdependencies. (Weske, 2012; Pradabwong et al., 2015)

Importance of BPM is also increasingly seen in the agri-food industry. As Verdouw (2010) discusses one of the drivers for improved business process management is the market changes. Agri-food companies need to be increasingly flexible in the demand-driven supply chains.

Wolfert (2010), Vorst (2005) and Novák (2016) claim that the increasing demands of government, consumers and business partners are driving agri-food companies towards more knowledge based operations, where ICT and BPM play an important role.

As discussed by Panagacos (2012) BPM in an organization has more functions and benefits which it can achieve:

- Function analysis – evaluates different activities executed by different parts of organization,
- Service analysis – identifies manual processes for possible automation,
- Process analysis – assesses end-to-end processes to identify improvements,
- Information analysis – defines the flow of information between stakeholders and optimizes it,
- Workflow analysis – assesses data workflow between systems.

This article describes the different modelling languages and their strengths for different purposes. Three most common business-modelling languages were used – Business Process Modeling Notation (BPMN), Unified Modelling Language (UML) and Event-Driven Process Chains (EPC). Example of a deliver-to-order process from a fruit farm is taken to show the main differences the modeling notations have.

In the first chapter the history of business process modeling languages is briefly described. In the following chapters two, three and four individual modelling languages UML, EPC and BPMN are described with their specific features. In the fifth chapter conclusion and account for future work is described.

## Materials and methods

The research has started with an analysis of available business process modeling notations. From these notations those most frequently used were chosen,

namely UML Activity diagram, BPMN and EPC.

Further literature review was conducted to identify the criteria to compare these notations. The adequacy of the notations in agri-food industry was further analyzed on a use case of fruit farm process deliver-to-order. As a secondary source of data for analysis, a review of published research materials was used.

## History of business process modeling languages

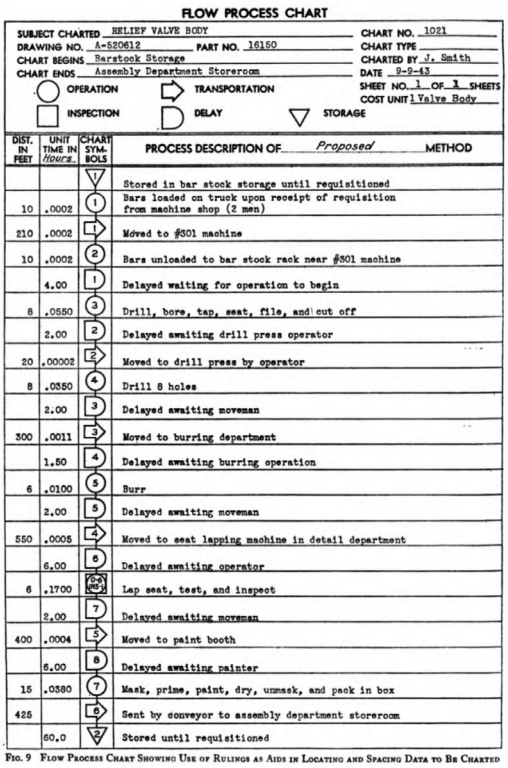
Panagacos (2012) argues that the first attempts to depict the organizational processes happened already in the time of ancient Egypt who adopted primitive forms of workflow systems used for engineering purposes.

However, when talking about the business process management in the modern time, then it is related to the attempt of permanent improvement of how business works. Therefore, Taylorism, Total Quality Management, Just In Time Management or Six Sigma initiatives are those which led to the need for a good business process modelling tool (Panagacos, 2012; Soare, 2012) (Figure 1).

In the early 20th century appeared a new management discipline of Scientific Management. It is represented mainly by the work of Frederick Winslow Taylor. He describes basic principles on how a good manager should improve his business. This included work simplification, time and motion studies and systematic work on improving the way in which the work is done.

It was another author Frank B. Gilbreth (Gilbreth, 1921) in 1921 who published his article Process Charts. Gilbreth intention was to introduce a tool, which could visualize a process in manufacturing. This is what he saw as a basis for further process improvement. He introduced a wide set of symbols. He also came up with the principle of putting the symbols from the top to bottom in the sequential order, which is a way how to show the flow of the process. (Graham, 2004; Krogstie, 2016)

The need of standardization was apparent and in 1947 American Society of Mechanical Engineers (ASME) came with such a standard and established a set of symbols known as the ASME Standard for Operation and Flow Process Charts. It was based on the Gilbreth work but generalized his symbols into six basic ones (American Society of Mechanical Engineers, 1947) (Figure 2).



FLOW PROCESS CHART

SUBJECT CHARTED RELIEF VALVE BODY — CHART NO. 1021
DRAWING NO. A-520612 — PART NO. 16150 — CHART TYPE
CHART BEGINS Barstock Storage — CHARTED BY J. Smith
CHART ENDS Assembly Department Storeroom — DATE 9-9-43
SHEET NO. 1 OF 1 SHEETS
COST UNIT 1 Valve Body

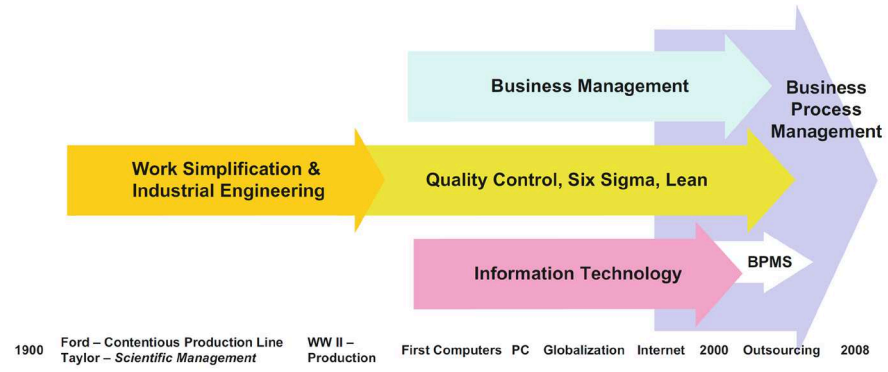
OPERATION — TRANSPORTATION — INSPECTION — DELAY — STORAGE

| DIST. IN FEET | UNIT TIME IN Hours | CHART SYMBOLS | PROCESS DESCRIPTION OF Proposed METHOD |
|---|---|---|---|
| | | ▽ | Stored in bar stock storage until requisitioned |
| 10 | .0002 | ○1 | Bars loaded on truck upon receipt of requisition from machine shop (2 men) |
| 210 | .0002 | ⇨1 | Moved to #301 machine |
| 10 | .0002 | ○2 | Bars unloaded to bar stock rack near #301 machine |
| | 4.00 | □1 | Delayed waiting for operation to begin |
| 8 | .0550 | ○3 | Drill, bore, tap, seat, file, and cut off |
| | 2.00 | □2 | Delayed awaiting drill press operator |
| 20 | .00002 | ⇨2 | Moved to drill press by operator |
| 8 | .0350 | ○4 | Drill 8 holes |
| | 2.00 | □3 | Delayed awaiting moveman |
| 300 | .0011 | ⇨3 | Moved to burring department |
| | 1.50 | □4 | Delayed awaiting burring operation |
| 6 | .0100 | ○5 | Burr |
| | 2.00 | □5 | Delayed awaiting moveman |
| 550 | .0005 | ⇨4 | Moved to seat lapping machine in detail department |
| | 6.00 | □6 | Delayed awaiting operator |
| 6 | .1700 | ○6 ⇨5 | Lap seat, test, and inspect |
| | 2.00 | □7 | Delayed awaiting moveman |
| 400 | .0004 | ⇨5 | Moved to paint booth |
| | 6.00 | □8 | Delayed awaiting painter |
| 15 | .0380 | ○7 | Mask, prime, paint, dry, unmask, and pack in box |
| 425 | | ⇨6 | Sent by conveyor to assembly department storeroom |
| | 60.0 | ▽2 | Stored until requisitioned |

FIG. 9 FLOW PROCESS CHART SHOWING USE OF RULINGS AS AIDS IN LOCATING AND SPACING DATA TO BE CHARTED

Source: American Society of Mechanical Engineers (1947)

Figure 2: Example of process from ASME methodology.

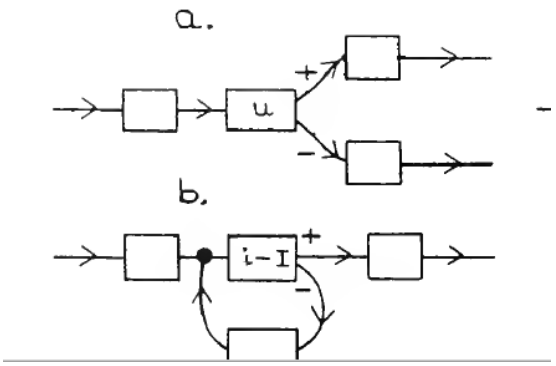



Source: Brocke, 2014

Figure 1: Evolution of business process management.

- Operation - when an object is being changed
- Transportation - when object is being moved to another place
- Inspection – when object is being checked and quality/quantity verified
- Storage – when object is being kept with no action
- Delay – when object is not being further processed until condition is fulfilled
- Combined activity – when activities perform at the same time

In the same time when flow chart idea was formed, another couple - John von Neuman and H. Goldstein developed another similar concept for programming purposes. In 1947, they published a paper in which they suggested a graphical way – flow diagram. Its main purpose is to represent computer algorithm (Goldstine and von Neumann, 1947; Morris and Gotel, 2006) (Figure 3).

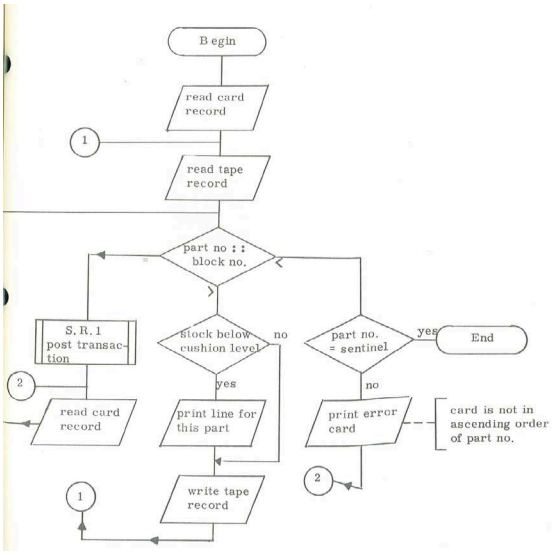



Source: Goldstine (1947)

Figure 3: J von Neuman, H. Goldstine flow diagram.

As Morris and Gotel (2011) who did an extensive research in history of flow charting note, there is a little material about early days of program design and about the development of flow-charting itself.

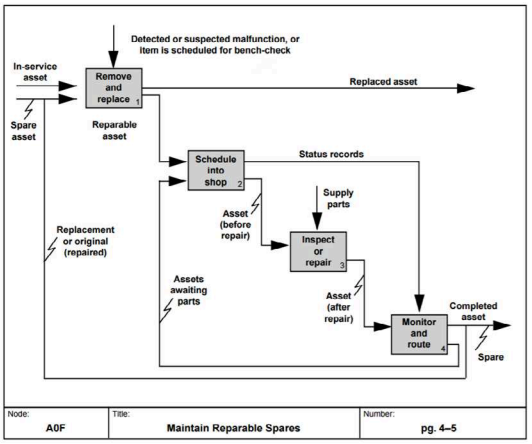
Only later in 1966 flowcharts were finally standardized by ECMA. It considered two basic usages for flowcharts. First was the program flow chart used to describe flow of a computer program. The other then Data Flow Chart used to show flow of data through the system (European computer manufacturers association, 1966) (Figure 4). Its flow chart notation is very much the notation used nowadays. Although the current standard is the ISO 5807:1985.




Source: European computer manufacturers association (1966)

Figure 4: ECMA flowchart notation example.

In parallel to how flow-charting developed there were also other initiatives which had as a goal possibility to capture process flows. One of them was the US Air Force ICAM (Integrated Computer-Aided Manufacturing) program, which was started in 1977. Within this program IDEF0 standard for functional modeling was defined. (Assembly of Engineering (U.S.). Committee On Computer-Aided Manufacturing, 1981; Godwin et al., 1989) IDEF0 shows well the interdependencies in a process. It also offers the possibility of process decomposition. Each process is split into functions with input and output flows, controls and mechanisms (Figure 5).




Source: Leonard, b.r.

Figure 5: IDEF0 process example.

In 1990s with the appearance of object-oriented programming, an effort to create a unified method, which will assist to the software development process was made. This lead to the Unified Modelling Language (UML). One of the UML charts is the activity diagram, which among other flows is used also for modelling of business processes. Activity diagrams are still very widely used for business process modelling nowadays. (Morris, 2012) We shall describe it in more details in one of the following chapters.

In 1992, there was also EPC (Event-Driven Process Chain) introduced by August-Wilhelm Scheer as a notation for semiformal charting of business processes. It was developed within ARIS (Architecture of Integrated Information Systems) framework, which was primarily used for SAP R3 enterprise resource planning system. (Scheer, 1999) Details about this notation will also follow in one of the next chapters.

In 2004, another notation – BPMN (Business Process Model and Notation) was introduced by BPMI (Business Process Management Initiative). Its main purpose was to achieve a notation which was well understandable by both business users and developers and enabled easy charting of business processes. Authors of BPMN used during its creation experience from existing notations - IDEF, UML Activity Diagram and EPC. (Object Management Group, 2011) This notation is also going to be described in detail in one of the following chapters.

### UML Activity diagram

Activity diagram is one of the UML behavioral diagrams. Interestingly the initial version of UML in 1995 did not contain the activity diagram. The state machine diagram with its concept that state changes in response to an input was the main tool to model behavior. Only later, the need for modeling the flow of activities was recognized and activity diagrams were introduced in 1996. (Morris, 2012)

Activity diagrams in UML are not purely intended for business process modelling. They can also be used for modelling of computational procedures or object-oriented models to describe methods and operations. Activity diagram has similar notation as flow chart. On top of that it allows to model parallelism.

In following Figure 6 example of such a parallelism modeling is shown. Activity Determine delivery date is running in parallel with Activity Reserve packaging material. Only after both of these activities are finished process continues to the next one – Pick fresh fruits.

Main components of an activity diagram are activity nodes connected with activity edges. There are following types of activity nodes:

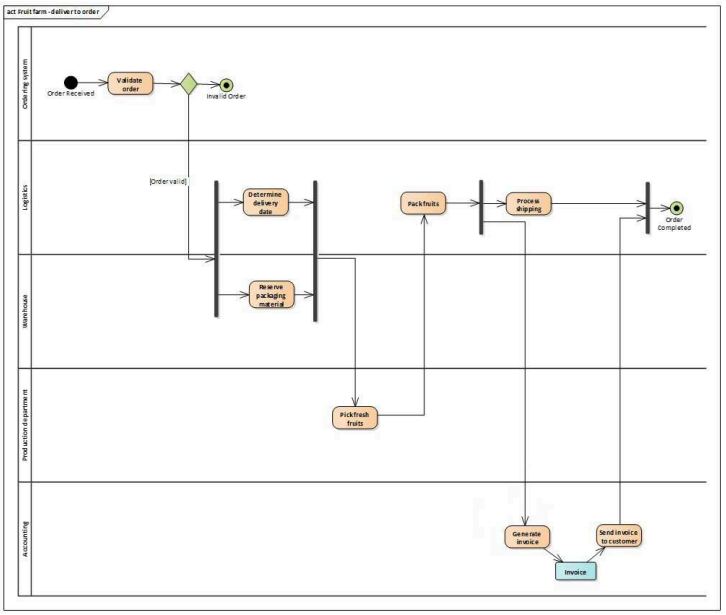
- Executable nodes – it is a behavioral step in the process. All the incoming and outgoing edges are control flows. It can also consume and produce data but only through an Object Node. In the following Figure 6, such executable node, which produces data, is activity “Generate Invoice”, which produces Object node “Invoice”.
- Object nodes – used to hold object during execution of an activity. In the following example, such node is the “Invoice”
- Control nodes – are special type of nodes used to control the flow within the process. There are different types of control nodes.
    - Initial one - starting point of the flow.
    - Final one - end point of the activity.
    - Split/Joint node – ensuring synchronization of the activity flow.
    - Decision node – decision point choosing between two or more alternative ways
    - Merge node – bringing together multiple flows. Unlike in joint node it is not synchronizing the process.

Apart of nodes there are following other objects within an activity diagram:

- Activity Edge – is a directed connection between two activity nodes. It can also hold a guard, meaning a value, which is evaluated. Only in case it is evaluated as true, process continues through this edge. Example of such a guard is the “Order valid” value in the Figure 6.
- Activity Partition – in order to split the process into parts, which have some common features, swim lanes can be used. (Object Management Group, 2015)

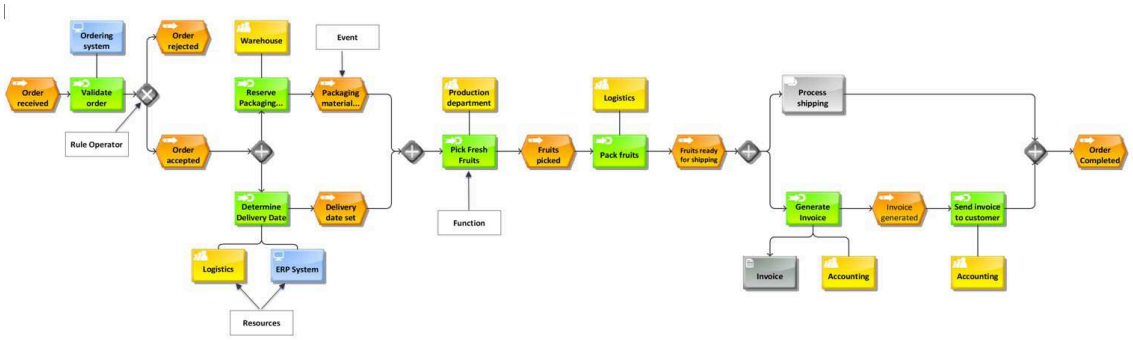
### Event-driven process chains

Event-driven process chain method developed in 1992 under SAP funding has different approach to model a process. Unlike Activity diagram, which has only one main component - activities, EPC has two components: Events and Functions.




Source: own work

Figure 6: Example of an activity diagram.




Source: own work

Figure 7: Example of an activity diagram.

Function is the active part of the diagram. It represents what is happening within the process. Fact that the function happens leads to the change of the state/event. In the Figure 7 the function "Pick fresh fruits" leads to the event "Fruits picked".

Events are then passive part of the diagram. It describes events/condition, which precede or follow some function. It can either describe event, which leads to some function, or it can describe how the situation changed by the function. In the following example, the event which precedes the "Pack Fruits" function is "Fruits picked". By running the "Pack fruits" function "Fruits ready for shipping" event is then triggered.

Apart from events and functions there can be also other components – Rules and Resources.

Rules are similar to the decision and fork/joint nodes in the activity diagram. They have however different notation and have wider function. Depending on if they precede or follow a function they have different meaning (Table 1).

| Operator | After a function | Before a function |
|---|---|---|
| OR | Decision – one or more path will be taken | Any combination of events will trigger the function |
| XOR | Exclusive OR Decision – one path will be taken | Only one event will be the trigger |
| AND | Flow splits into two parallel paths | All events must occur to trigger the following function |

Source: own work

Table 1: EPC rules.

Resources are another component of EPC. They serve as a tool to model the relationship between the process and the business environment. There are multiple types of resources:

- Organization unit – responsible for the function to be undertaken
- Systems – represent computer and software applications needed
- Data – representing the input and output data for the function
- Knowledge – knowledge needed and relevant to the function
- Information Carriers – represent the media on which the information is being stored
- Products – showing what products are being delivered by the function
- Objective and Measures – business objective met by the function
- General Resources – other non-specific resources (Davis, 2001)

### Business process model and notation

Object Management Group (2011) claims BPMN notation has two major goals. First is to achieve a notation, which is easily readable and understandable to all stakeholders. Secondly, it enables visualization of XML languages designed for business process management systems such as WSBPEL.

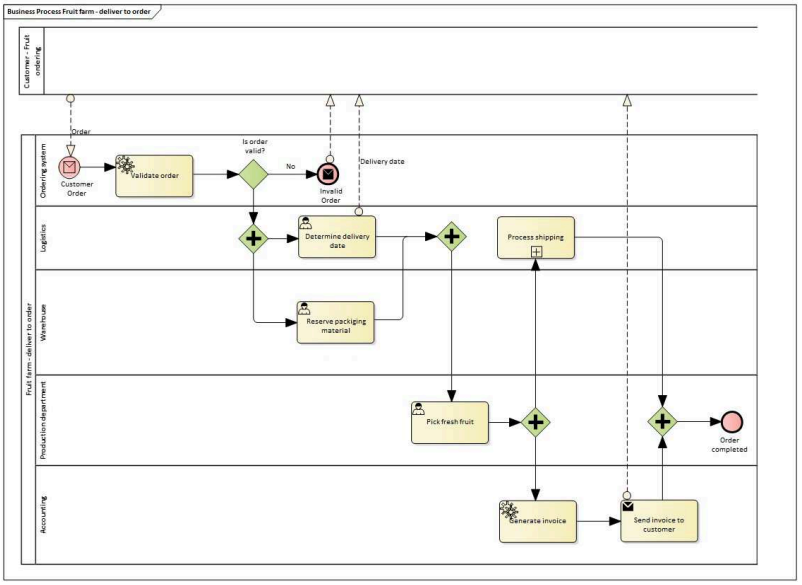
With BPMN 2.0 the scope of the notation was extended. It does not only serve to show processes, but also shows choreographies meaning the messages exchange between process participants, collaborations showing interaction of different participants and conversations showing the high-level perspective on the collaboration of different participants.

BPMN has five basic elements:

- Flow objects – these are the basic graphical elements of the business process. There is the *activity* element representing the work, which is being done, event element representing the trigger or a result of a process and the gateway which controls the flow of the process.
- Data – is used to provide information what input is required for a certain activity or what data is produced by such an activity.
- Connecting objects – serving for connecting different elements together. Basic one is the *sequence flow*, which connects activities and determines their order in the process. Another is the *message flow* determining how the different participants communicate with each other. Last one is the *association* used to link other BPMN artifacts together.
- Swim-lanes and pools – are graphical containers showing the different process participants
- Artifacts – these elements serve to provide additional information for the process, which cannot be modeled by the other elements.

(An example Figure 8).

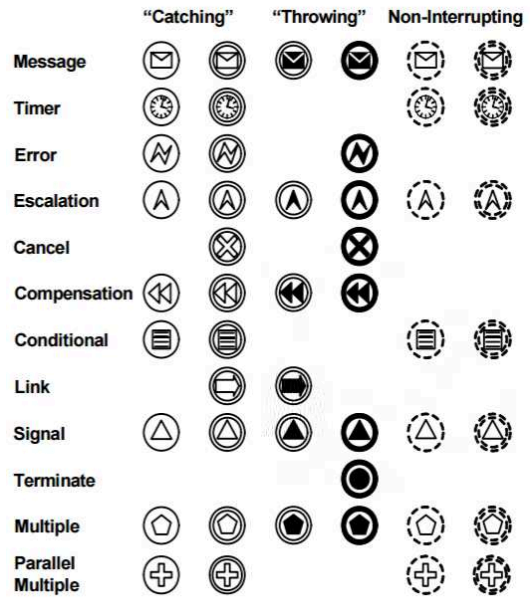
While there is only limited number of the basic BPMN elements, they have different variants, which is bringing the additional complexity




Source: own work

Figure 8: BPMN process.

of BPMN diagrams. This is especially true for the event element, which has many different variations, each of them with a specific meaning. This brings additional complexity to the modelling notation (Figure 9).




Source: Object Management Group (2011)

Figure 9: Event Element variations.

## Results and discussion

In the following chapter differences among notations are described. They are clustered into five main categories:

- Notations modelling differences
- Ability to describe complex processes
- Understandability of the notations
- Usability& User acceptance
- SOA preparedness

### Notations modelling differences

Following table summarizes the main differences in the modelling possibilities of each discussed notation (Table 2).

### Ability to describe complex processes

Generally, BPMN and EPC considered as those having bigger variety for modelling. They have more elements, which can be used.

EPC has for example special elements for data, knowledge, information carriers or products. None of these are in BPMN or UML Activity diagrams. These can be modelled only by the general artefact element.

| | EPC | UML Activity Diagram | BPMN |
|---|---|---|---|
| Diagram context | Process-oriented modeling (business oriented) | Object-oriented modelling (IT oriented) | Process-oriented modeling (business oriented) |
| Active element | Function – round edged box | Activity – round edged box | Task – round edged box |
| Event element | Hexagon element used for depicting all events; used also to describe post-function state of the process | Only start and end event available | Wide variety of elements depicting the event – circle with symbol inside |
| Ability to decompose process | Special process interface element used to link processes | Activity with rake style icon indicates subprocess | Activity element with plus icon indicates subprocess |
| Flow of data | Only flow of events and activities shown. | Only flow of activities shown. | Separation of control and message flow.<br>Apart of sequence of steps flow of information across pools can be depicted. |
| Modelling of parallelism | AND connector used to fork activities to show parallel run and then join them. | Horizontal thick black line used to fork and join parallel run. | Special fork/join gateway used to model parallelism |
| Modeling of complex decisions | Decision point representing either OR or XOR in Boolean logic | Just simple decision point representing OR in Boolean logic | Apart OR and XOR also event based gateway and gateway for complex decisions. |
| Actors | Organizational unit element to indicate who is the actor | Swim-lanes and pools used to distinguish different actors | Swim-lanes and pools used to distinguish different actors |
| Loop in diagram | No special element for loops. Can be modeled by combination of decisions and functions. | No special element for looping. Can be modeled by combination of decision step and activity. | Special loop activity existent |

Source: own work

Table 2: Comparison of modelling notations.

BPMN on the other hand has a wider variety of event elements. There are no events except of start and end event in UML Activity diagram. As Rashedul et al. (2011) notes, UML was designed for object-oriented modelling. For showing states and events of a dynamic object there is a different UML diagram, namely the state machine one. EPC has for events only one element but its description is enabling the variability.

Furthermore, White (2004) compared business processes modelling patterns between UML Activity Diagram and BPMN. He claims that both notation can adequately model most of the patterns. So even UML activity diagram does not have such a big variability, in the real use this is not an issue. As Recker (2009) notes even BPMN has theoretically bigger variability but it is rather a theoretical feature. In reality, the complexity is not being widely used.

### Understandability of the notations

OMG, which is responsible for both UML and BPMN sees BPMN as the main tool for business process modelling claiming "… BPMN is to provide a notation that is readily understandable by all business users …" (Object Management Group, 2011) The UML AD is rather seen as technically oriented. One should note that there is no substantial evidence that BPMN was superior to UML Activity diagram in understandability. One of the reason is that they share same notation for the basic elements.

Jošt et al. (2016) conducted a study where they compared UML Activity Diagram, EPC and BPMN for their understandability. They found out that BPMN is not well understandable in process diagrams with lower complexity. It was outperformed by both UML Activity Diagram and EPC. On the contrary, in the complex diagrams EPC was outperformed by both BPMN and UML Activity diagrams. They concluded that UML Activity diagram is the most versatile. In addition, Peixoto et. al (2008) was investigating the comprehension of BPMN and UML Activity diagram from the readability perspective. In his experiment, both notations were equally understandable by research subjects.

### Usability and user acceptance

Another research focused on how users accept different notations and what might be the usability issues.

Kruczynski (2010) made an empirical study about BPMN and EPC acceptance. His respondents were claiming in the questionnaire that EPC has a clearer layout, is more logical, comprehensive and easier to implement. Interestingly enough, when letting the same group to do the modelling they did less mistakes in BPMN than in EPC. He concludes BPMN to be more stringent in modelling which leads to less modelling mistakes.

Birkmeier et al. (2010) focused on comparing usability of BPMN and UML Activity diagram. He compared effectiveness, efficiency and satisfaction with the notations. Although BPMN is considered superior of both notations, his empirical study did not confirm that. Both BPMN and UML Activity diagram are proven as equally usable. Furthermore, some problematic aspects of BPMN were identified. One of them is the separation of data and control flows, which misleads less experienced users. In all the other discussed notations, there is only one type of activity flow. Users have to thus have sufficient knowledge about this significant BPMN difference in order to correctly understand the BPMN process. Another issue is the flexibility of usage of BPMN. They claim that it is promoting rather sequential modelling style, which is then decreasing the process flexibility. Recker (2009) notes another usability problem for BPMN and that is its complexity. He suggests that it is in the interest of learnability and user acceptance to actually reduce complexity. Wahl and Sindre (2006) then conclude that although BPMN has an easy basic graphical notation, it requires significant training for more complex features.

### SOA preparedness

Next criterium is whether and how the notation is ready for the Service oriented architecture (SOA). SOA's goal is to abstract IT from its physical implementation and publish IT resources as re-usable services. It reduces the semantic gap between the business process and the implementation. BPEL (Business Process Execution Language) - standard for developing executable processes - is then a way how to build business processes based on the re-usable services. Having thus the ability to convert business process into an execution language could dramatically shorten the development lifecycle. (Jurič, 2008) When the process is well designed, it can be then executed by business process engine with minimal changes. While BPMN was built with intention to enable translation to BPEL, UML Activity diagram is missing this feature. (Geambasu, 2012)

Kruczynski (2010) notes that both EPC and BPMN are transformable to BPEL. Because BPMN was designed with the respect to BPEL, there are more transformation patterns between BPMN and BPEL

than EPC and BPEL. However, as Kruczynski (2010) explains it is the tool used which makes the quality of the BPEL process not just the existence of the transformation pattern.

## Conclusion

This paper described history of business process modeling notations, three most common notations – UML, BPMN and EPC and their differences. All three notations can adequately model business processes as demonstrated on the Fruit farm deliver-to-order process example.

They do however differ in some specific features. In some aspects, each of the languages always outperforms the others. Important is that except of some general objective features where the languages differ, there is also a lot of subjective perception of how the single notations perform. Therefore, both depending on the specific usage of the notation and depending also on the specific user group, different notation can be optimal for being selected. When comparing the notations, no specific characteristic was identified which would favor one of the notations from the agri-business perspective. As a result, the topic for future work is to prepare a decision framework, which will enable the user to pick the right notation for the specific situation with respect to defined criteria.

*Corresponding author:*
*Ing. František Kožíšek, MSc.*
*Department of Information Engineering, Faculty of Economics and Management*
*Czech University of Life Sciences Prague, Kamýcká 129, Prague 6, Suchdol, 160 00, Czech Republic*
*E-mail: kozisekf@pef.czu.cz*

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