A Comprehensive Analysis on Business Process Modelling Standards, Techniques and Languages

Youseef Alotaibi

Department of Computer Science, College of Computer and Information Systems, Umm Al-Qura University, Makkah, Saudi Arabia

Abstract
Literature shows that there are many business Process Model (PM) tools, techniques and standards. However, choosing the right tools and techniques with which to model BPs is very complicated as there are not as many guidelines to describe the concepts involved. Thus, the modellers should know the purpose of their model in order to select the right techniques and tools. Categorizing the different business PM techniques, tools and standards into different groups with the same functions and characteristics can make logical sense of them. In this paper, we have categorized the existing business PM techniques and tools into three groups: graphic, execution and interchange standards and have provided a comprehensive analysis on the existing business PM techniques and tools. Our proposed literature review can help in enhancing manufacturing practice as it provides a right picture for the business analysts and modellers regarding what are the most satiable techniques for their cases and requirement. Thus, the manufacturing and companies' process time, cost and performance can be enhanced and improved their revenue.

Keywords: *Business Process Management (BPM); Business Process Modelling (PM); Business Process (BP); Literature Review*

1. Introduction

Business process management (BPM) is a systematic approach to improve an organisation's business processes (BPs) where the BPs are the set of coordinated activities and tasks performed by people in order to achieve the organisational goals and objectives. BPM activities aim to create efficient and effective BPs which can be adapted in a rapidly changing business environment [1].

BPM is usually the top business priority for organizations and constructing a BP capability is one of the main challenges for senior executives. Business Process Modelling (PM) is the act of capturing and graphically describing organizational processes. Business PM is widely used by organizations as a way to increase BP awareness and knowledge, and develop or change organizational structures, information systems (IS), and web services [2-3].

Business PM is a way to support BPs by using several techniques, methodologies, models, and systems to design, control, and analyse BPs, where many resources are used: human, applications, technology, and organizations [4].

The literature shows that there are many business PM tools, techniques and standards [5] and to understand these techniques, we have categorized business PM standards into three groups: (1) graphic standards; (2) execution standards; and (3) interchange standards. Graphic standards have been divided into 2 levels: graphical standards at enterprise level, such the United Modelling Language (UML) [6-7] and Business Process Management Notation (BPMN), and graphical standards at process level, such as Architecture of Integrated Information Systems (ARIS) [8] and Colored Petri Net (CPN) [9]. Furthermore, the graphical standards at enterprise level are divided into three types: workflow techniques, such as flow chart, notation techniques, such as UML and BPMN, and production techniques, such as Computer Integrated Manufacturing Open System Architecture (CIMOSA) [10]. The graphical standards allow users to describe BPs transitions and flows using diagrams. Execution standards, such as the Business Process Execution Language (BPEL) [11] and the Business Process Modelling Language (BPML) [12] are used to computerize BP deployment and automation. Interchange standards, such as the XML Process Definition Language (XPDL) [13] and Business Process Definition Meta-Model (BPDM) [14] are used to facilitate data portability, such as BP design portability in different graphic standards across the Business Process Management System (BPMS) and different execution standards across different BPMS.

Literature shows that there are several works have been done for categorizing the business PM techniques and tools. For example, [15] classified the most popular graphical business PM techniques, such IDEF, UML, RAD, etc., and explained the techniques components. Furthermore, [16] only reviewed the most popular graphical and execution business PM techniques by explaining the techniques components. However, in this paper, the most popular graphical, execution and interchange business PM techniques and tools have been reviewed by explaining them, their benefits on the manufacturing and production purpose and drawing their advantages and disadvantages. Thus, our proposed categorized business PM standards, techniques and tools can make the right picture for selecting the best practical business PM techniques.

Manuscript received September 5, 2020
Manuscript revised September 20, 2020

DOI: 10.22937/IJCSNS.2020.20.09.29

Choosing the right tools and techniques with which to model BPs is very complicated because a large number of techniques have been proposed but there are not as many guidelines to describe the concepts involved. However, the modellers should know the purpose of their model in order to select the right techniques and tools. Therefore, this paper presents an overview of research in the business PM domain. It provides a comprehensive analysis of the existing business PM standards, techniques and tools. We outline several guidelines to create good business PM.

This paper is developed over the following sections. Section 2 presents an overview of the BPM history and lifecycle and presents an overview of BPs and business PM. Section 3 presents our methodology. Section 4 describes a comprehensive analysis of the existing graphical business PM techniques at the enterprise level. Section 4 describes a comprehensive analysis of the existing graphical business PM techniques at the process level. Section 5 describes a comprehensive analysis of existing execution business PM techniques. Section 6 a comprehensive analysis of existing interchange business PM techniques. Section 7 outlines several guidelines to create good business PM. Finally, section 8 presents the conclusion and implications.

2. Business Process Management (BPM)

BPM has been an important priority for organisations since the 1990s as companies try to increase the number of products and services they offer, improve their relationships with customers, decrease the time it takes to launch new products and services and increase customer satisfaction. One of the major challenges for senior executives is to build a BP capability as it is used by the organization to understand, analyse and communicate organizational knowledge and make an automatic BP. Also, BPM is used to establish quality manuals, establish control mechanisms, assess and define added value and create an automatic workflow. Therefore, BPM tools and techniques are considered to be one of the most valuable and useful assets of business organizations [17].

BPM uses methods, techniques and software to support the BPs to design, enact, control and analyse operational processes involving organizations, humans, applications, documents and all other information sources. Software tools support the management of the operational processes as the BPMS [18].

2.1 BPM Life Cycle

Different techniques are used in the BP life cycle for the effective management of BPs. BPM is a cycle methodology where several perspectives of BPs are investigated during its various stages. In order to effectively understand BPM terminologies and features, we start with an overview of the BPM life cycle. According to [19], the BPM life cycle comprises four stages: process design, system configuration, process enactment and diagnosis.

According to [20], the BPM life cycle comprises six stages: BP modelling, integrating, executing, analysing and monitoring, measuring and optimizing.

- In the BP modelling stage, the process models are used to graphically capture, design and simulate the BPs.
- In the BP integration stage, the process elements are connected to exchange information in order to achieve the business goals and objectives.
- In the BP execution stage, the BP is deployed and executed within the BPM execution engine.
- In the BP analysis and monitoring stage, the graphical administrative tools are provided to illustrate the processes which are in progress and completed and to integrate the business metrics and the key performance indicators within the BP descriptions.
- In the BP measurement stage, definition of familiar business metrics is related to computational measurements.
- In the BP optimization stage, which refers to process improvement, process flows of all sizes involved across any application are optimized and BP design and BP maintenance are coordinated.

2.2 Business Process (BP)

BPs contain the transformation of inputs to outputs and express the behaviour of organizations. The BP is a set of activities whose final purpose is the production of a specific output which has value to the customer. Each BP which has a goals and objectives can be affected by events that have happened in other BPs or in the external world. It is the central concept used to model the business.

BPs can be classified into core or primary and supportive or secondary BPs. A core BP starts from outside the organization, such as the chain of BP activities which realise product delivery to the customers. On the other hand, a supportive BP generates the conditions for the core BP to carry out. Many authors have defined BPs in different ways [21]. Table 1 presents the most importations definitions and comments:

Table 1: Different BP Definitions.

Ref No	Definitions	Comments
[22]	BPs are a set of activities acquiring one or more inputs and generating output as rate to the customer.	The definition shows the importance of BP to organizations and highlights how business activities can be achieved which meet customers' expectations.
[23]	BPs are a set of organizational procedures that are structured together to achieve business goals.	BPs are made up of several business organizational activities, such as goals, people, objectives etc.
[24]	BPs are a set of internal organizational procedures or activities that work together to achieve a business organization's goals and objectives to fulfil the customers' expectations.	This definition first discusses the importance of BP activities within the organization, especially internal activities (e.g. strategies, goals, policies, objectives etc.); and secondly, how these activities can assist in increasing the satisfaction of customers.
[25]	BPs highlight how to execute the work rather than how to model the business services and products.	BPs are more concerned with the implementation of organizational activities rather than modelling them.

[26]	BPs are ways to simply design how to achieve specific tasks in the organizations.	BP is only used to narrow the business activities.
[27]	BPs are a complete set of related dynamic business organizational activities that are scientifically worked in order to meet customers' expectations or fulfil the business goals and objectives that have been defined at the business strategic level.	A set of structured organizational activities needs to work together to increase customer satisfaction and meet company's goals.

2.3 Business PM

Business PM is an essential element in BPM as it enhances an understanding of business concerns and communication between stakeholders. It is used for visualizing BP operations for a more thorough understanding and analysis. They are used as a medium of communication between stakeholders, such as employees, developers and executives. It increases stakeholders' ability to understand BPs and to make rational decisions to enhance the traceability and understandability of organizational activities.

Business PM is a well-accepted method within the business organizational sector for structuring BPs. There are three important pillars to business PMs: model, strategy, and operations. A business model includes the knowledge of creating an organization, deliverables and how to identify business goals and objectives. Business strategies provide rules and guidelines to fulfil all model-related elements. Business operations include peoples, processes and technology, whereas a different people groups work together to complete organizational goals with the help of IS services [28].

Business PM is used to achieve the following:

- It supports BP reengineering and improvement through BP analysis and simulation.
- It creates an appropriate IS that can support the organization by providing the descriptive business model to learn.
- It facilitates the ability of the organization to share its understanding of BPs by using common BP representations which enhances understanding and communication. This occurs by agreeing to adopt a well-defined set of BP concepts to be used by different stakeholders.
- It supports the decision-making process during BP control and execution.

Table 2: Different BP Modelling Definitions.

Ref No	Definitions	Comments
[29]	Business PM is a way to support BPs by using several techniques, methodologies, models, and systems to design, control, and analyse BPs, where many resources are used: human, applications, technology, organizations etc.	This definition only focuses on how the processes are going to be operationalized, however, process clarification at the business strategic level is also important.
[30]	Business PM aims to provide information on real world activities at an abstract level rather than a detailed description of business activities and hence the information is used to reduce the complexity of real world activities.	This definition represents the BP as a slice of reality with only a brief description. However, in the context of business PM, a detailed description of each activity is required.
[31]	PM is a way to assist humans to understand, describe and document process-related information using effective diagrams rather than explanations using text	This definition shows that the BP and other process-related activities within the business organization can be described easily using different UML diagrams: activity diagrams, state charts, use cases, sequence diagrams, etc.
[32]	PM in an organization is a method that focuses on the management of organizational activities in business transactions.	The BP activities need to be managed in a way that goals can be achieved.
[33]	PM is the logical and temporal order of related business functions that have been performed on the process objectives.	Business activities have been used as functions that fulfil the process objectives.
[34]	Business PM is a method to understand and redesign the BP to better support customer services.	This definition views the business PM as a technique for understanding and redesigning BPs.

There are many techniques and methods available, such as BPMN, BPEL, *i** modelling language, etc. Many authors have defined business PM in different ways. Table 2 presents the most important definition and comments.

3. Literature Review Methodology

Our review reports on academic publications on business PM techniques and tools over the 30 years from 1990 to 2020. It includes all the business PM tools, standards, techniques and methodologies encountered in the literature and follows an extensive, systematic search within the academic peer-reviewed literature. It reviews past research into the business PM graphical, execution and interchange techniques and tools.

It is important to establish an efficient method to process this large amount of literature while capturing the essential elements of the overall picture. Therefore, our literature review of business PM comprises two stages, as depicted in Figure1. In the first stage, we searched the papers using several keywords such as "business process", "business process modelling", "business process management", "business process modelling tools", "business process modelling techniques", "business process modelling standards" and "process model". We filtered the results based on the paper's title, read the abstract of the selected papers and further filtered them to identify the most relevant papers to the topic of business PM techniques and tools. In this stage, we identified 296 journal papers and 233 conference papers that were potentially suitable for inclusion in the literature review.

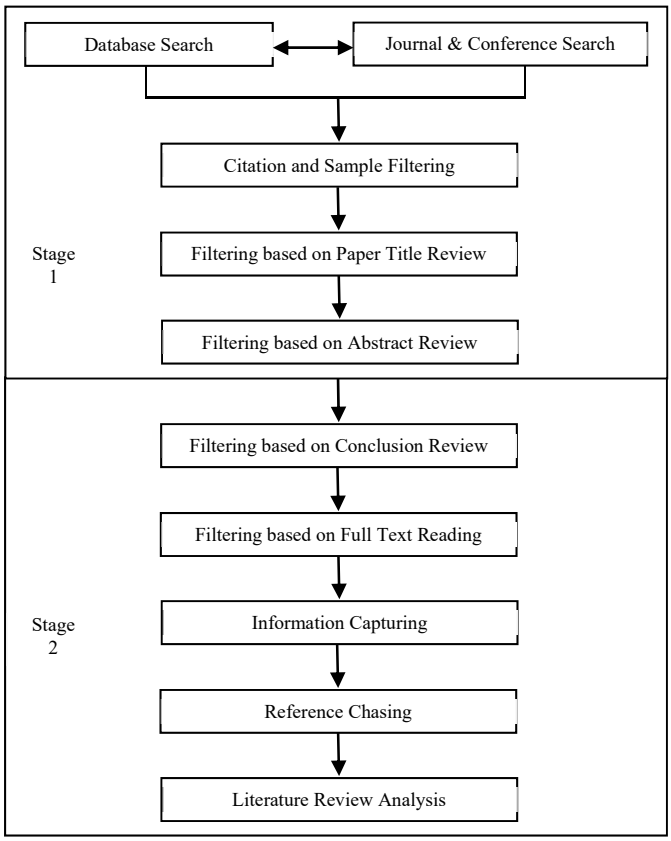

Fig. 1. Literature Review Methodology

In the second stage, we read the conclusion of the selected papers and then read the full text of the papers to choose the papers that were most relevant to our literature review topic, selecting 53 journal papers and 36 conference papers as being the most relevant to our topic.

Business PM techniques address different aspects of BPs, such as activity sequence, organizational responsibilities and resource allocation. These business PM techniques are based on a graphic notation and are driven by practical rather than theoretical foundations.

Choosing the right tools and techniques with which to model BPs is very complicated because a large number of techniques have been proposed but there are not as many guidelines to describe the concepts involved. However, the modellers should know the purpose of their model in order to select the right techniques and tools. Categorizing the different business PM techniques, tools and standards into different groups with the same functions and characteristics can make logical sense of them. For example, existing business PM techniques and tools have been divided into two different categories: intuitive graphical modelling techniques and rigorous paradigm modelling techniques. The intuitive graphical modelling techniques, such as Event-driven Process Chain (EPC), are used to capture and understand BPs for project-scoping tasks and for discussing business requirements. However, rigorous paradigms modelling techniques, such as Petri nets, are used in mathematical format and are used to analyse BPs, to execute BPs and to simulate and experiment using BP scenarios [35].

There are three reasons why business PM is useful for supporting business goals: (1) they describe BPs where the BP is modelled in order to be able to be described by a human or a machine; (2) they can analyse BPs using either a qualitative or quantitative methods; and (3) they enact BPs for simulation purposes or to support BP execution. As BPs are complex, the language designers provide four different modelling views, each one focusing on one aspect of BPs: (1) functional view; (2) dynamic or behavioral view; (3) informational view; and (4) organizational view. The functional view presents the function dependencies between BP elements, such as activities and sub-processes. The dynamic or behavioral view describes the time and control aspects of BPs, such as when the things happen and for how long. The informational view describes the objects manipulated by BPs, such as the real-world object (machine tool and raw material) or abstract objects (transactions and orders), and the organizational view represents the actors and roles in the organization which are responsible for the execution of the BP activities.

Table 3 compares the different business PM techniques according to the aforementioned BP aspects or views. There are three support levels for each BP view: '+/+', '+/-', and '-/-'. '+/+' refers to the technique which contains the coherent set of constructs to represent the view in question without judgment as to the set expressiveness. '+/-' refers to the core technique which does not support the view at hand while the technique designers make a conscious effort to develop the technique. '-/-' refers to the technique that does not provide the complete set of the constructs to represent the view [36].

Literature shows that there are several works have been done for categorizing the business PM techniques and tools. For example, in [37], the authors classified the most popular graphical business PM techniques, such IDEF, UML, RAD, etc according to four different categories: (1) descriptive models for learning; (2) descriptive and analytical models for decision support to process development and design; (3) analytical models for decision support during process execution and control; and (4) enactment support models to information technology. Furthermore, the tools associated each of the selected graphical business PM techniques have been reviewed. However, it only reviewed the most popular graphical business PM techniques by explaining the techniques components and the most suitable software tools that could be used to draw them.

Table 3: Comparison of Different BP Modelling Techniques According to the various BP views

Techniques	View			
	Functional	Dynamic	Informational	Organizational
DFD				
RAD		+/+	-/-	
RID	+/+	+/+		+/+
IDEF0	+/+			
IDEF3		+/+		
CPN		+/+		
BPMN		+/+		
EPC		+/+	+/-	+/-
UML	+/+	+/+	+/+	
BPML		+/+	+/-	-/-
BPEL		+/+	+/-	
BPDM	-/-	+/+		+/+
XPDL		+/+	+/-	

In [15], the authors grouped business PM approaches into four categories: (1) activity-oriented approaches; (2) object-oriented approaches; (3) role-oriented approaches; and (4) speech-act-oriented approaches. The activity-oriented approaches, such as Integrated Definition for Function Modelling (IDEF) tend to identify BPs as specific activities or task order. The object-oriented approaches, such as Object Oriented (OO) and *i** are associated with object orientation, such as inheritance, encapsulation and specialization. The role-oriented approaches, such as Role Activity Diagram (RAD) involve the role in the set of activities to carry out the particular responsibilities. The speech-act-oriented approaches, such as Multi-Agent Information System (MAIS) depend on the speech act theory under the language and action perspective and view the communication process as a four-phased loop: proposal, agreement, performance and satisfaction. However, it only reviewed the most popular graphical business PM techniques by explaining the techniques components.

In [16], the authors grouped the most popular graphical and execution business PM approaches into four categories: (1) traditional process modelling languages, such as IDEF, EPC, RAD, etc; (2) object-oriented languages, such as UML; (3) dynamic process modelling languages, such as WFMC, BPEL; and (4) process integration languages, such as ebXML. However, it only reviewed the most popular graphical and execution business PM techniques by explaining the techniques components.

Therefore, in this paper, we have categorized business PM standards into three groups: (1) graphic standards; (2) execution standards; and (3) interchange standards. Graphic standards have been divided into 2 levels: graphical standards at enterprise level, such the UML and BPMN, and graphical standards at process level, such as ARIS and CPN. Furthermore, the graphical standards at enterprise level are divided into three types: workflow techniques, such as flow chart, notation techniques, such as UML and BPMN, and production techniques, such as CIMOSA. The graphic standards allow the users to state the BPs transitions and flows using diagrams. The execution standards are used to computerize the BPs deployment and automation. The interchange standards are used to facilitate data portability, such as BP design portability in different graphic standards across the BPMS and different execution standards across different BPMS. These three standards will be explained in the following three sections with examples of the existing techniques.

In this paper, the most popular graphical, execution and interchange business PM techniques and tools have been reviewed by explaining them, their benefits on the manufacturing and production purpose and drawing their advantages and disadvantages. Thus, our proposed categorized business PM standards, techniques and tools can make the right picture for selecting the best practical business PM techniques.

4. Graphical Standards at Enterprise Level

The graphical standards allow the users to state the BPs transitions, roles, information flows and the decision points using graphical diagrams. There are different types of graphical standards at enterprise level, such as flow chart techniques, Data Flow Diagram (DFD), Gantt Chart (GC), Unified Modelling Language (UML), Workflow techniques, Business Process Modelling Notation (BPMN) and Event-Driven Process Chain (EPC). In order to make it more understandable, the graphical standards at enterprise level are divided into three types: workflow techniques, such as flow chart, notation techniques, such as UML and BPMN, and production techniques, such as CIMOSA. These different techniques will be explained in the following subsections.

4.1 Workflow Techniques

There are some business PM techniques used the workflow graphical diagrams styles, such as flowchart DFD and Gantt chart. Thus, we consider them as the workflow techniques and they will be explained in the following subsections.

- ***Flowchart Techniques***

The flowchart is a formal graphical representation of the BP, such as data, operation and flow direction in the program logic sequences. The flowchart model is possibly the first BP notation used. In 1921, a flowchart was proposed by Frank Gilbreth, a member of the American Society of Mechanical Engineers (ASME). It is used to show the flow of BPs from the beginning point to the end. It contains several symbols, such as activities, start point, end point, decision, input, output and department, and these symbols are linked by lines to show the correct sequence. There are four main types of flowchart techniques: document, data, system and program flowcharts. The document flowchart shows the control over the document flow throughout the system; the data flowchart shows the control over the data flow in the system; the system flowchart shows the control of the physical and resource level; and the program flowchart shows the control in system program. This technique is flexible and can be explained in different ways. Also, it can be used easily and drawing the processes does not require a long time. However, it cannot be read easily when there are a lot of events

in the flowchart since there are no differences between the main activities and sub-activities [38].

- ***Workflow Technique***

The workflow technique is the computer facilitation or automation of BPs where information, documents and tasks are passed between different participants as an action which is dependent on several practical rules. It shows the task flow between people and the computer applications in the organization. The workflow technique is a method used to analyse, model and improve BPs. The work management system (WMS) is used to identify, generate and control workflow executions using software where its execution order is driven via the computer representation of the logical work. This technique is used by the workflow development process to capture the related process information.

There are four stages in this process: gathering the information, modelling the BPs, modelling the workflow and implementing, verifying and executing the model. The main concepts and terms used in the workflow technique and their relationships are shown in Figure 2. There are several advantages of the workflow technique. For example, they have a short learning time, and changes can be made easily. Moreover, they can be used in combination with other systems and can be decentralized. However, when using this technique, human contact could be lost, felt control and there will be a lack of motivation [39].

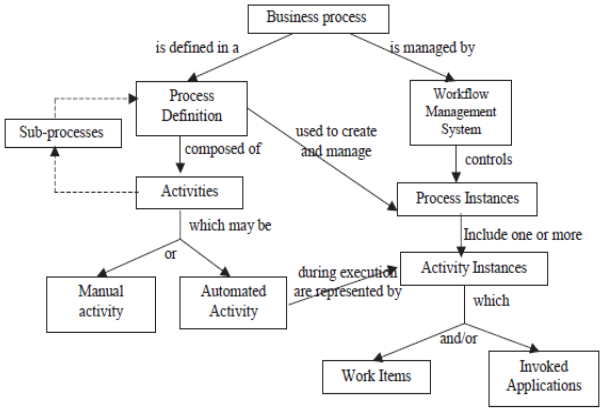

Fig. 2. Basic Concepts of the Workflow Technique

- ***Gantt Chart (GC)***

The Gantt Chart (GC) is a type of bar chart which illustrates a project schedule, showing the beginning and the end and the terminal or summary dates by which key elements of the project should be completed. Both the terminal and summary elements comprise the work breakdown structure (WBS) for the project. It is a matrix listing all tasks and BPs activities on the vertical axis to perform them in the processes. In this technique, every row shows a single activity, identified by a name and number. The columns show the estimation of the duration of the activity duration, the skill level required to perform the activity and the name of the person who has been assigned to the activity, heads the horizontal axis. The next column shows the duration of the project. This type of graphic provides information on the activities in relation to the timeframe for the project and is an easy-to-produce graphical representation of BPs activities but it does not show the dependencies between the activities. In addition, this technique can be understood easily as it has become commonly used to represent different activities and phases of WBS projects [24].

- ***Data Flow Diagram (DFD)***

A data flow diagram (DFD) is a graphic representation of the data flow throughout the IS. It is used to visualize the structured design of data processes and shows how BPs connect together via the data stores and how BPs relate to reality and users through diagrams which illustrate data or information flows from one place to another. Using this technique, the analysts can specify BPs logically as they can describe what the BPs are doing rather than how the BPs are doing it. Every BPs can be separated into sub-processes at a low level in order to show the details. There are four symbols used in the DFD: square, round rectangle, arrow and open-ended rectangle. The square is used to represent an external entity which could be source data or destination data. The round rectangle is used to represent the process by which the input and output data is obtained. The arrow is used to represent the data flow while the open-ended rectangle is used to represent the data stores, such as the database. This technique can be easily understood, drawn and amended.

DFD represents the seamless flow of information, in an information system, from one process to another. It represents a transfer of complex information from one point of the production process to another. Before adopting a new system, a system analyst conducts a thorough analysis of the current system to understand information flow. That is why system documentation is an important component of this transition from the old system to a new one. DFD is important in studying the relationship between the components and processes involved in converting inputs into outputs. Any manufacturing firm that uses inputs to produce output through processes would use DFD to communicate to the current users [40].

4.2 Notation Techniques

There are some business PM techniques considered as the standard and notation techniques, such as UML, BPMN and EPC. These notation techniques will be explained in the following subsections.

- ***Unified Modelling Language (UML)***

The Unified Modelling Language (UML) is the standard graphic description language used to specify, construct, visualize and document software systems' artefacts, other non-software systems and business PM by using object-oriented (OO) methods. It was developed by the Object Management Group and Rational Software in 1997 and is used to represent the collection of engineering practices which are successfully established in complex and large systems modelling. It can be used to cover conceptual things, such as system functions and BPs, and concrete things, such as database schemes and programming language classes.

The UML combines different techniques from the entity relationship diagram of data modelling, workflow business modelling, component modelling and object modelling. It synthesises the notation of three different techniques: the Booch method, object-oriented software engineering (OOSE) and the object modelling technique (OMT) by fusing these techniques into a common, single, practical modelling language. The UML comprises nine different diagrams showing the specific dynamic and static aspects of the systems, described in Table 4. In addition, 13 OO notations are used in the UML to capture the whole behaviour and attributes of the modelled objects [41].

UML focuses on proper documentation of business procedures making it easy to follow steps and sequences in the production process. As a result, the manager is able to make informed decisions on areas that need improvement. A production firm in its initial design stages a can use this modeling language to simplify complex processes. It runs on any type of application regardless of hardware, network, programming language, or operating system. In a manufacturing environment, this enterprise level modeling technique is used in modeling complex processes and in documentation. Any manufacturing firm regardless of size would use this because it can model any application at the enterprise level.

Table 4: Unified Modelling Language (UML) Diagrams.

Diagrams	Description
Class Diagram	Used to describe the system structures which are built from different classes and relationships.
Object Diagram	Used to express the possible object joining the particular class diagram.
State-chart Diagram	Used to express the possible system or class states.
Activity Diagram	Used to describe the actions and activities that take place in the system.
Sequence Diagram	Used to show one or a set of sequences of messages that are sent within several objects.
Collaboration Diagram	Used to completely describe the collaboration within several objects. It is used to represent the interactions between the objects.
Use Case Diagram	Used to illustrate the relationships between different use cases which are identified in plain text in order to describe one part of the whole system functions. It is used to represent the system behaviour.
Component Diagram	The component diagram, which is a special case of the class diagram, is used to describe the software system components.
Deployment Diagram	The deployment diagram, which is a special case of the class diagram, is used to describe the software system hardware.

- ***Business Process Modelling Notation (BPMN)***

The Business Process Modelling Notation (BPMN) is a graphical representation for specifying BPs in a business PM. It was released by the Business Process Management Initiative (BPMI) organization in 2004. This standard is the main enabler of business PM which is a new scheme in the business architecture world which aims to control changes in order to improve BPs. The BPMN is used to provide a notation that can be readily understood by business users, including business analysts who generate the first process draft for the technical developers who implement these technologies in order to perform BPs. Therefore, the BPMN can bridge the gap between business analysts and IT. Furthermore, this technique is used to ensure that XML languages, such as the BPML and the Business Process Execution Language for Web Services (BPEL4WS) which are designed to execute BPs can be visually expressed within the common notation.

The BPMN contains one diagram known as the Business Process Diagram (BPD) which is designed to be used and understood easily and can model complicated BPs. The BPMN BPD can be directly mapped to the BPML because they are developed by using the solid mathematic function by the BPMI. This standard can be used to model abstract or public processes, internal or private processes and global collaboration processes in different granularity levels. However, it is very complicated to sketch the BPMN elements on paper, and it is complicated to use the BPMN to visualize the BPEL because there is an incompatible difference between the BPEL and BPMN [42].

Managers and analysts are finding this process very useful in business performance evaluation. Businesses that lack proper documentation make it impossible to track and ensure consistency in achieving desired objectives. Process mapping, process analysis, and process simulation are some of the processes related to business PM. A production facility producing products that need to meet specific quality standards on a consistent basis would need this as it tracks the desired goal concerning consistency in quality.

- ***Event-Driven Process Chain (EPC)***

The event-driven process chain (EPC) was developed by the Institute for Information Systems (IWi) at the University of Saarland in Germany. It is a language widely used in the workflow component of the SAP R/3 system and the ARIS Toolset of IDS Scheer AG, and it can be simply and easily picked up by non-technical users. It works as the ordered graph of functions and events and supports the execution of parallel processes. It is the logical operators while its semantics and syntax are not well defined.

EPC clearly demonstrates activities and events in easy to understand diagrams simplifying complex BPs [43]. Manufacturing companies can use it as a blueprint in process workflows because of its ordered graphs. It is an enterprise level modeling technique because of its ordered graphs and any manufacturing company who would like to put its resources into best use by minimizing wastage would use EPC.

- ***i* Model***

The *i** modelling framework is an agent-oriented requirements modelling language appropriate for the early phase of system modelling to understand the system's problems. It is a powerful tool in software requirement engineering to model the organizational tasks, actors, processes and goals. It is used to obtain real and understandable requirements and to explore why processes are performed in a particular way. It is used to identify strategic actor relationships. This framework comprises two important components: the Strategic Dependency Model (SDM) and the Strategic Rationale Model (SRM).

The SDM is used to describe the network of the relationships between actors. In the SDM, every node represents an actor and every link between two nodes shows that one actor is dependent on the other actor. It provides a description for the external relationships between the actors. The aim of the SDM is to provide indications about why the business process is organized in a certain way. However, it cannot adequately support the exploration, suggestion and evaluation of other solutions for the process, which the SRM can do [44].

The SRM is used to support and describe why the actors can have different ways to organize their work, such as a different configuration for Strategic Dependency networks. SRM has four main nodes: goal, soft goal, resource and task, and two main links: mean-ends link and the task decomposition links. It is used to model the internal relationships between actors. This model can systematically explore possible new BP designs.

- ***Unified Enterprise Modelling Language (UEML)***

The idea of a Unified Enterprise Modelling Language (UEML) emerged during the ICEIMT'97 conference, with the aim of providing an underlying formal theory for enterprise modelling languages. UEML is an on-going attempt to develop theories, technologies and tools for integrated use of enterprise and IS models expressed using different languages. It keeps the existing models as they are and establishes relationships between them in an explicit and usable way, supporting, consistency checking, model-to-model translation, automatic update reflection and other services across modelling language boundaries. Therefore, it intended as an intermediate language - or a hub - through which different languages can be connected, thereby facilitating a web of languages and of models expressed in those languages.

It comprises: (1) a structured approach to describe enterprise and IS modelling languages; (2) a common ontology to describe the semantics of modelling constructs and thereby interrelate construct descriptions at the semantic level; (3) a correspondence analysis approach to determine correspondences between constructs; (4) a quality framework to define and evaluate the quality of enterprise modelling languages to aid language selection; (5) a meta-meta model to organise the UEML; and (6) a set of tools to aid its use. UEML has several disadvantages. For example, it is weakly structured, it mixes requirements of different levels of detail and it does not attach rationales to requirements [45].

UEML exists to integrate various operations in a smart company or enterprise networks. A modeling language connects various layers in business functions. It brings together various forms of modeling such as goal modeling, business PM, resource modeling, and structural modeling. It also expresses the logic of flow decisions between key decision points. Companies that promote teamwork and information sharing most of the time should consider UEML as it enables information sharing and creates commitment among members. It is an enterprise-level modeling technique because in a production set up, it allows interdepartmental information sharing.

4.3 Production Techniques

There are some business PM techniques used for the production purpose, thus they are considered as the production techniques, such as VSM, CIMOSA and GERAM. These notation techniques will be explained in the following subsections.

- ***Value Stream Mapping (VSM)***

Value Stream Mapping (VSM) is a technique applied to the value chain to analyse and reengineer the materials flow and required information to bring the product to the customer. It provides a set of standard icons as the common language to describe the manufacturing processes. These icons map into three categories: material flow, information flow and general icons. It is mainly purposed to analyse and improve the disconnected flow lines in the manufacturing environments. It is depended on five phases: (1) select the product family; (2) current state mapping; (3) future state mapping; (4) defining the work plan; and (5) work plan achievement.

VSM is a technique used in manufacturing to conduct analysis, and subsequently design the flow of information and materials that will eventually deliver a superior product or service to the end user. It is a technique used in a lean manufacturing environment. There is a close link between VSM and manufacturing process and is mostly used in logistics and supply chain or service-related industries. As an enterprise level modeling technique, this is the basic tool to identify and reduce waste, lower process cycle time, and carry out process improvement. A shipping company would find VSM very useful in logistics and supply chain processes as it tracks materials from production to inventory, shipping, and delivery [46].

VSM has several advantages, such as it forms the basis for lean production implementation and relates the internal manufacturing process to the facility the all supply chain. Furthermore, it can display both the product and information flows and link the demand forecast and products planning to the flow shop control and production scheduling. The information related to the production time and inventory levels are included in VSM.

However, it has several disadvantages, such as it has limited accuracy level as it is a paper and pencil based technique. It cannot guarantee or enable operations to generate the enduring strategic advantage over time. It has low number of handled versions and thus it cannot address as a standard method. In addition, it is a static tool which cannot handle the complexity or uncertainty and cannot describe the dynamic behaviour.

- ***Computer Integrated Manufacturing Open System Architecture (CIMOSA)***

Computer Integrated Manufacturing Open System Architecture (CIMOSA) is a full-fledged framework proposed to analyze, design and make operational large-scale integrated manufacturing systems. It has been developed by the ESPRIT Consortium AMICE as a series of ESPRIT Projects (EP 688,

5288 and 7110) over the period 1985–1995. There are more than 21 companies and research units from seven European countries had directly contributed to CIMOSA, plus additional partners in validation or sister projects (e.g. VOICE, CODE, CIMPRESS). It can be used in decision support for engineering and evaluating enterprise operation and in model driven operation monitoring and control.

The CIMOSA has several major outcomes: (1) to be the pivotal foundation of generalized enterprise reference architecture and methodology (GERAM) together with GRAI and PERA, (2) to be the baseline for standards development on enterprise modeling and integration at the European and international levels (CEN ENV 40003, CEN ENV 12204, ISO/IS 15704, ISO/DIS 14258 among others); and (3) to inspire enterprise modeling and workflow tool developers (e.g. ARIS Toolset, FirstSTEP, PrimeObjects, CimTool, to name a few).

It has several strengths. For example, it relies on its enterprise modelling approach based on systems theory, process algebra and object orientation. Also, it views a single enterprise or a networked enterprise as a large set of concurrent processes executed by communicating resources and exchanging objects and messages.

It has several core concepts for which a syntax and semantics are provided: event, process, activity, operation, resource and object view. It is worthwhile to point out that the activity concept is the structuring concept in the sense that it federates all other constructs by means of well-defined relations with them. An activity is the locus of action which utilizes time and resources to perform a task in order to transform an input state into an output state. Each task requires capabilities or skills. A process is a partially ordered set of activities, the execution of which will result in the achievement of some objective of the enterprise. This execution needs to be enabled by some trigger, called event [47].

The CIMOSA focus on construct a framework for enterprise modelling, a reference architecture, an enterprise modelling language and an integrating infrastructure for model enactment supported by a common terminology. In addition, it uses four perspectives: (1) the function view describes the functional structure required to satisfy the objectives of an enterprise and related control structures; (2) the information view describes the information required by each function; (3) the resource view describes the resources and their relations to functional and control structures; and (4) the organization view describes the responsibilities assigned to individuals for functional and control structures.

- ***Graph with Results and Actions Interrelated - GRAI Integrated Method (GRAI-GIM)***

Graph with Results and Actions Interrelated (GRAI) as developed by the GRAI Labouratory of the University of Bordeaux, resulted from production management studies initiated at the Labouratory as early as 1974. It aims to model a production management system in order to be able to define precisely the specifications needed to select a software package for a Computer Aided Production Management (CAPM) system. It consists of three subsystems. The physical system transforms materials into products and this is coordinated by a hierarchy of control or decisional systems. The information system carries out all data transfers between and within these subsystems. In the life-cycle of a manufacturing system, the analysis phase is a study of the current structure and behaviour of the system, identifying constraints, goals and possible inconsistencies with cross-checking using GRAI-grid and GRAInet. The design speciation phase determines the functional speciation, the basic framework and the general behaviour of the desired system.

The GRAI Integrated Method (GIM) is a further development of the GRAI model in 1988, which uses existing systems design and cross-checking methods to help achieve simultaneous consideration of the decision, information and physical systems. GRAI-GIM aims to support all life cycle of the manufacturing system that has to be designed. Therefore, it consists of the user-oriented and the technical-oriented methods where the user-oriented method transforms the user requirements into the user specification in terms of function, resources, decisions and information, and the technical-oriented method transforms the user specification into the technical specifications in terms of information, organization and manufacturing technology components [48].

There are some similarity between GRAI-GIM and CIMOSA architecture. GRAI-GIM presentation consists of three parts: conceptual reference model known as GRAI, formalisms to describe the GRAI model and structured approach. It covers all life cycle of the manufacturing system except the operation and decommissions phases. However, its four views are different than CIMOSA as it introduces the decision and physical view where the physical view models describe the functional attributes of the physical elements. Also, it is less formal than CIMOSA.

- ***ENV 40 003 Enterprise Modelling***

The European pre-standard ENV 40 003 is a framework for enterprise modelling and integration developed in 1991 by WGI. The aim of ENV 40 003 is to provide a common conceptual high level framework where the distribution, extending and virtual enterprise concepts can be defined, documented and shared with all partners in the enterprise. It is depended on the input from CIMOSA and it includes several concepts: (1) covering modelling levels suitable for different life cycle stages, such as from the requirements definition to the design specification and from the design specification to the implementation description; (2) providing generic concepts can be particularly specialised to industry and then to the specific enterprise; and (3) classifying concepts according to the function, information, resource and organisation concepts.

ENV 40 003 does not have any strict classification or separation for its concepts into particular views. For example, in

the function view the enterprise activity can have input and output identified and resource capabilities to different degrees related to the model level. Thus, the view represents the focus of concern and it does not represent the classification of the modelling concepts [49].

- ***Generalised Enterprise Reference Architecture and Methodology (GERAM)***

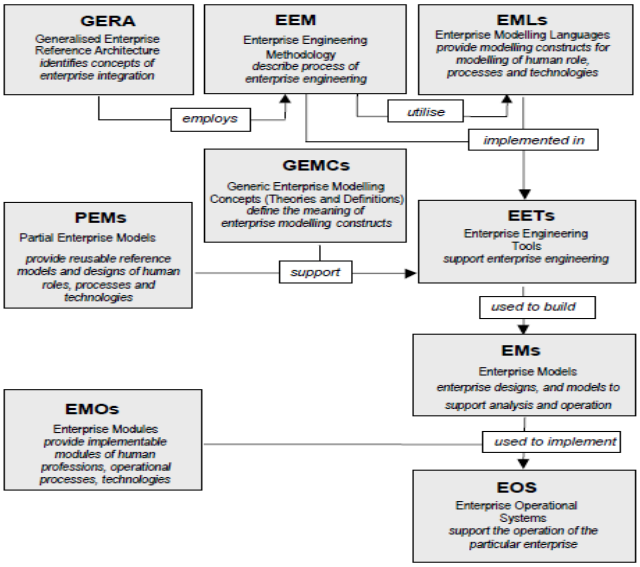

Fig. 3. GERAM Framework Components.

Generalised Enterprise Reference Architecture and Methodology (GERAM) is the generalised enterprise architecture framework for BPR and enterprise integration developed in the 1990s by the IFAC/IFIP Task Force on architectures of enterprise integration. It defines the set of components that are recommended to be use in the enterprise engineering. It is the enterprise reference architecture which can be used on the whole life cycle of modelling the enterprise integration project as it uses on the definition, functional, specification or design, the detail design, physical implementation and operation to obsolescence.

As shown in figure 3, GERAM includes eight major components: (1) Generic Enterprise Reference Architecture (GERA) which identifies the enterprise generic concepts used in the enterprise integration projects, such as enterprise systems life cycle, business PM and modelling languages for different users (system designers, business users, etc); (2) Generic Enterprise Engineering Methodologies (GEEM) which describes the generic enterprise integration processes; (3) Generic Enterprise Modelling Languages (GEML) which identifies the generic constructs for the enterprise modelling that have been adopted to different people needs; (4) Generic Enterprise Modelling Tools (GEMT) which identifies the generic enterprise integration implementation; (5) Enterprise Models (EM) which represents the enterprise operation using the generic constructs of modelling language; (6) Ontological Theories (OT) which formalises the enterprise related concepts in the term of important properties and axioms; (7) Generic Enterprise Models (GEMs) which defines the reference models that capture the common concepts to many enterprise in order to increase the efficiency of the modelling process; and (8) Generic Modules (GMs) which defines the applicable products, such as tools and integration infrastructures to be utilized in the enterprise integration [50].

5. Graphical Standards at Process Level

The graphical standards allow the users to state the BPs transitions, roles, information flows and the decision points using graphical diagrams. There are different types of graphical standards at process level, such as CPN, ARIS, Non-Structured Activity Analysis (ACNOS), These different techniques will be explained in the following subsections.

5.1 Role Activity Diagram (RAD)

The role activity diagram (RAD) presents a graphical view of BPs from the perspective of individual roles. It highlights roles, responsibility and interactions. Roles are an abstract notation of the behaviour used in order to describe the desired organizational behaviour. This technique provides different perspectives of BPs and particularly enhances communication. It can be read and understood easily and intuitively in order to present a detailed view of the BPs and also allows a better understanding of the business activities. However, business objectives are not described in this technique. In addition, obtaining an overview can be difficult because BPs are presented as a sequence of activities and this technique does not allow for BPs decomposition [51].

RAD describes the real flow of work characteristics within an information system representing actual activities by showing the systematic sequences of such activities. It also explains the workflow behind any system design. A manufacturing company involved in production of products that follow a systematic procedure in auto manufacturing would use this. It is important as it shows the flow of activities from one process to another. It is a process level modeling technique and acts as a guideline in systematic sequence in production.

5.2 Role Interaction Diagram (RID)

A role interaction diagram (RID) is a graph of BP outcomes joining between the RAD and Jocobson's Object Interaction Diagram (JOID). The BP activities are connected to the roles in the matrix. The activities are shown vertically on the left axis while the roles are shown horizontally across the top. The human interactions are shown by the horizontal lines. The BPs can be represented by both text and symbols. This technique is more complex than the flow diagram. While it can still be read easily and intuitively understood, it can be messy and difficult to build. Significant information can be lost since the inputs to activities and outputs from activities are not included in the model BPs.

The new BPs activities or roles cannot be easily inserted when the existing diagram is edited. Therefore, large sections of the diagram should be moved in order to allocate space for new BP activities or roles to be inserted. The workflow design can be the best used of this technique, such as the processes involving the coordination of the connecting BPs activities [37].

5.3 Integrated Definition for Function Modelling (IDEF)

The Integrated Definition for Function Modelling (IDEF) is a family of techniques used to support the paradigm which is able to address the business BP requirements of the organization and the various business areas. In the 1970s, IDEF were proposed by the US Air Force thorough establishing the Integrated Computer Aided Manufacturing (ICAM) program. Modelling activities, behaviour and data requirements are resulted from the first selecting of the Structured Analysis and Design Technique (SADT). In total, there are sixteen IDEF family techniques: IDFE0, IDFE1, IDFE1X, IDFE2, IDFE3 . . . IDFE13 and IDFE14 [52]. The IDFE0, IDEF1, IDEF1X and IDFE3 techniques are the most helpful for business PM and will be explained in the following four subsections.

- ***IDEF0***

The IDFE0 modelling technique is used to graphically represent the structure of BPs and complex systems, such as organizations. This technique specifies function models which show the high level of the BPs activities indicating the main activities and input, output, control and mechanisms related to the main activities. There are three information types contained in the IDEF0 technique: graphic diagram, glossary and text which are cross-referenced to each other. The graphic diagram consists of arrows, boxes, box-arrow interconnections and the association relationships. This technique is suitable for implementation as computer software because it has strict rules. It can be easily analysed and improved since the data and control can be identified by working backwards from the outputs to the inputs. However, in the IDEF0 technique, the activity sequences can be embedded [53].

- ***IDEF1***

The IDEF1 modelling technique is an information modelling method used to define the information which has been collected, stored and managed by the organization, the rules governing the management of information, the problems resulting from inadequate information management and the logic relationships in the organization reflected in the information. The representations, such as the entity-relation diagram (ERD) are applied by the IDEF1 modelling technique to achieve its goals.

- ***IDEF1X***

The IDEF1X modelling technique is the semantic model standard used to model the business rules and involves four main terms: entities, attributes, message and relationship. It refines these into three different levels: (1) entity-relationship level; (2) key-based level; and (3) fully attributed level. The entity-relationship level defines the entities and the relationships existing between them. The key-based level resolves the business rules by using the primary key of the entities. The fully attributed level resolves the business rules by using the primary and non-key attribute.

- ***IDEF3***

The IDFE3 uses the scenario as the main organizing structure to explain how BPs work. The IDFE3 Process Description Capture techniques are used to capture aspects of the BP behaviour and were developed to explicitly describe the BPs. The Process Flow Description (PFD) mode, which is used to describe how things actually work in organizations, and the Object State Transition Description (OSTD) mode, which is used to summarize the acceptable object transitions in the particular processes, are the main modes in the IDFE3 modelling technique. The main IDFE3 technique notations are a set of squares, oblong boxes, circles and arcs to link them. This technique can be used in several areas such as software process definition and improvement and BPR [54].

5.4 Coloured Petri Net (CPN)

The Coloured Petri Net (CPN) technique is the graphic-oriented language used to design, simulate, specify and verify the systems. The computer science group at Aarhus University in Denmark developed the CPN tools, extending the Petri net by changing the symbols for colours [55]. This technique contains a set of modules which have transitions, arcs and network of places. Four types of analyses are enabled by CPN tools: interactive simulation, occurrence graphs, automatic simulation and place invariants. There are several benefits to using this technique. For example, it can be used to describe a large diversity of different systems and can explicitly describe states and actions. Furthermore, CPN tools can present hierarchic descriptions and interactive simulations and the results can be directly represented on CPN diagrams.

CPN represents states using places and transitions. Circles represent places and triangles represent transitions. There are also arcs that exist between transitions and places that outline input and output places. CPN show the current process that is executing. Manufacturing companies making beverages can use it to identify a problem in the production stages. It is a process-level modeling technique because it shows executing stages and the problems at those stages.

5.5 Architecture of Integrated Information Systems (ARIS)

Architecture of Integrated Information Systems (ARIS) started as the academic research of Prof August-Wilhelm Scheer in the 1990s arose from a project between SAP AG and the University of Saarland. It aims to provide a framework spanning the gap between business requirements and ISs. For example, it aims to provide a precise way of expressing BPs and to allow effective communication and detailed analysis of them.

Moreover, it aims to provide an unambiguous basis for the development of the necessary IS to support BPs.

ARIS provides a structure to organize different types of model and objects of an organization and to identify their relation to each other. It contains of five views: (1) Organization view; (2) Data view; (3) Function view; (4) Product/service view; and (5) Process (control) view. Organization view represents the static models of the structure of an organization and it includes departments, people resources and roles in hierarchical organisation charts, technical resources. Data view represents the static models of business information and it includes data models, knowledge structure, information carriers, technical terms and database models. Function view represents the static models of process tasks and it includes function hierarchies, business objectives, supporting systems and software applications. Product/service view represents the static models of the structures of products and services and it includes product trees, products and services. Process (control) view depicts the dynamic models showing the behaviour of processes and how they relate to the resources, data and functions of the business environment. The process view includes EPCs, information flow, materials flow, communications diagrams, product definitions, flow charts and value chain diagrams [56].

ARIS provides general approach, well-documented methodology, and strong tools of business PM to support re-engineering processes throughout stages of the life cycle. It is a re-engineering process backed with thorough documentation of events. It also looks at the bigger picture involving process design, application processing, workflow, and management. It is important in systems design as it provides a detailed description of BPs. It sums up process design and workflow into an easy to understand process. Manufacturing firms use it to look at the different units as one.

5.6 Non-Structured Activity Analysis (ACNOS)
5.7

Non-Structured Activity Analysis (ACNOS) is an interdisciplinary project funded by the French ministry of research and technology over the period 1994 – 1997 and devoted to analyse the structured and non-structured activities in the production systems.

ACNOS project aim was to develop methods or tools to model and analyse the structured and non-structured activities in the BPs for the production environments. In ACNOS, the functional aspects are modelled using IDEF3x which is an extension version of IDEF3 derived from the CIMOSA formalism. It caters for the structured and semi- structured BPs. This formalism supports the qualitative analysis and simulation of the BPs using the time data for each activity.

In ACNOS, the economic model and cognitive model formalisms were provided for the analysis of the enterprise economic performances and decision making in order to model the resource and organisation aspects. The economic model is depended on the performance indicators or quantitative measures and performance derivers related to the activities and opened to the activity based costing analysis concepts. It provides the foundation for identifying the dynamic tableaux-de-board for the system managers. Furthermore, the cognitive model defines the human capabilities in the term of competencies, knowledge trees and cognitive strategies where competencies identify the obtained knowledge and know how, knowledge trees identify the important knowledge for the provided task and cognitive strategies identify the dynamics of the decision making related to the task. It can be used to identify the job profile provided by the human resources or needed by the activity.

It is an interdisciplinary approach concerned with developing business PM in an unstructured environment. Unlike a structured process whose act of sequence involving process steps can be determined, a non-structured process has no known sequence or steps in processes [57]. It is mostly common where a creative and innovative team is designing a completely new product. It is a process level modeling technique and is applicable where creativity and innovation is desirable. Table 5 and 6 compares the different graphical standards of business PM techniques at both enterprise and process levels.

Table 5: Different Graphical Standards of BP Modelling Techniques

Techniques	Description	Attributes	Advantages	Disadvantages
Flow Chart	Graphical representation	Actions flow	Flexible, simple	Too large, different notations
DFD	Descriptive diagram	Data flow	Easy to draw and understand	Just shows the data flow
RAD	Graphical diagram for object state transaction	Individual roles flow	Includes business objects and intuitive to read	Cannot be decomposed.
RID	Matrix processes representation for coordination activities	Roles and activities flow	Displays complex processes and intuitive to understand.	Hard to edit the diagram and does not include essential information
GC	Matrix representation	Duration and activities flow	Simple and easily represent and control performance	The dependencies are not clearly represented
IDEF0	Text, glossary and graphical representation	Input, output, mechanisms, control and activities flow	Shows details and possible to build the software	Does not represent the roles or interpret activities' sequences
IDEF3	System behaviour aspects	Relationships between activities	Easy to understand and possible to build the software	Requires several diagrams to describe the processes
CPN	Graphic OO language	Transition, arcs and network of places	Formal mathematical representation that is easy to understand	Large model and time consuming when modelling
Workflow	Computer facilitation and automation	Information, rules and procedura	Changes can be made easily, a short learning time	A lack of a particular notation

	for the business process	l rules flow		
BPMN	Graphical diagram targeted business analysts	Activity event flow from start event to end event	Enables roles to be defined at different levels	Hard to sketch on paper and does not have XML interchange format.
EPC	Ordered graph of events and functions	Supports parallel processes execution	Simple and easy for non-technical users	Semantics and syntax not well defined
*i**	Social actors, resources, tasks, goals and soft goals	SDM, SRM, analyse and design tools	Obtain information in an early phase of the software engineering process	Cannot be used without prior technical knowledge
UML	Graphical diagram targeted software development	Activities flow from start node to end node	Supports signal sending and receiving at the conceptual level, supports waiting and processing states, and decomposes an activity into sub-activities	Complex, a lack precise syntax and semantics, does not fully capture significant synchronisation kinds, and cannot be used without prior technical knowledge

6. Execution Standards

The execution standards are used to computerize BP deployment and automation. They can be used to design BPs to be deployed in the BPMS. There are two main types of execution standards: (1) Business Process Modelling Language (BPML); and (2) Business Process Execution Language (BPEL). The BPEL standard is widely adopted in different software suites although the BPML standard may address the business processes semantics better than the BPEL standard.

6.1 Business Process Modelling Language (BPML)

The Business Process Modelling Language (BPML) is an eXtensible Markup Language (XML) process definition language to describe the process structural representation and execution semantics. It extensively uses XML in two different places: (1) using XML as a presentation and serialization format for the BP descriptions; and (2) using XML Schema descriptions (XSD) to specify the data types that manipulated by the processes.

BPML has several high-level constructs that are not usually found in programming languages, such as notions of schedules, transactions, compensation, and correlation properties. A schedule is a sequence of time events and it can associate with a process, where the process is launched by the first event and the subsequent events launch different parts of the process. BPML supports inter-process transactions as long their invocation is performed within an atomic activity. In addition, it supports the notion of a compensation process whose aim is to undo the effects of processes. Finally, processes have correlation properties to support related process instances to each other.

In BPML, business PM runs on the engine element to elements' semantics. BPML is a good balance of a graphical and block-oriented model although it is an XML-based code and thus, is one of a few formally completed languages. The BPML process code has graphic-oriented constructs, such as parallel paths and loops, and block-oriented constructs, such as variables and structured exception handling where the block-oriented constructs allow programming the BPML BP, making it the leading light of the process-oriented programming paradigm [58].

BPML was designed to execute the BPs in contemporary web service-based BPMS, such as the Intalio business PM. It has its roots in Pi-calculus which examines the interaction between two processes based on the message flow between them.

6.2 Business Process Execution Language (BPEL)

BPEL is an XML-based programming language which has been standardised by OASIS, becoming the de-facto standard for web service composition. BPEL is an industrial standard for modelling web-service-based business processes. It provides support for executable and abstract business processes. BPEL version 2.0 is the version which was approved in 2007. BPEL 2.0 is the evolution of the previous BPEL version 1.1 released in 2003 and contains several improvements, such as improved variable manipulation, improved correlation, enriched fault handling, dynamic parallel flows, local partner links, improved loop handling, and extension mechanism. BPEL is coupled with the Web Service Definition Language (WSDL) version 1.1 since its communication model is based on the WSDL's concept of port types and operations.

Table 6: Different Graphical Framework and Standards of Enterprise Integration and Production

Techniques	Advantages	Disadvantages
UEML	Keeps the existing models as they are and establishes relationships between them in an explicit and usable way.	Weakly Structured. Mixes requirements of different level of details. Does not attach rationales to requirements. May include too complex requirements.
CIMOSA	Analyse, design and make operational large-scale integrated manufacturing systems. Relies on its enterprise modelling approach based on systems theory, process algebra and object orientation. Covers both functional and behavioural aspects of CIM systems.	It is complex. There is lack of computer tools to support the whole methodology.
GRAI-GIM	Provides the systematic approach to model the decision system of manufacturing enterprise.	It is not a tool for system design as it only provides support for requirements definition and analysis.

		Uses redundant models as same concepts can be modelled twice. Does not support detail design. Does not cover operation and decommissions phases of manufacturing system.
ARIS	Spans the gap between business requirements and IS. Allows transforming business related issues step by step into information technology solutions. Avoids redundancies which can occur when objects in a process model are used more than once.	It is complex. Semantics and syntax not well defined.
ACNOS	Easy to understand and possible to build the software	Requires several diagrams to describe the processes. There is lack of computer tools to support the whole methodology.
ENV 40 003	It is a standard for enterprise modelling.	Lack of consistency, convergence and interoperability of modelling tools and methodologies. Does not cover all enterprise life cycle.
GERAM	Generalised enterprise architecture framework for BPR and enterprise integration. Uses on the whole life cycle of modelling the enterprise integration project.	It is complex. Requires several diagrams to describe the processes.
VSM	It forms the basis for lean production implementation. It can display both the product and information flows. It includes the information related to the production time and inventory levels.	It has limited accuracy level as it is a paper and pencil based technique. It cannot guarantee or enable operations to generate the enduring strategic advantage over time. It is not a standard method as it has low number of handled versions.

Several extensions have been proposed for BPEL. For example, BPEL Extensions for Sub-Processes provides the means for the invocation of a BP as a sub-process of another BP. Furthermore, BPEL Extension for People (BPEL4People) addresses the human interactions and introduces a new type of the essential activity uses human tasks as an implementation. This extension is based on WS-Human-Task specification that identifies human tasks, including their behaviour, properties and the set of operations used to manipulate human tasks. Also, the AO4BPEL introduces aspect-oriented extensions to BPEL. Adaptive-BPEL is another BPEL extension which is based on the aspect-oriented concepts to support the development of differentiated and adaptive BPEL processes. Moreover, the C-BPEL is an extension which incorporates context information and uses it for service composition, while the BPEL4Chor is an extension used to model the choreographies [24].

However, programming in BPEL is a complicated task and the previous research only shows how BPM and design standards, such as UML and BPMN, are transferred to BPEL web services or how BPEL is transferred to Petri nets. The literature review shows that there is no existing work that implements and builds a web service after modelling and designing a BP that can be easily understood by IT professionals.

Table 7: Different Execution Standards of Business Process Modelling Techniques

Techniques	Advantages	Disadvantages
BPML	Supports the zero-code design-driven deployment concept. Encourages scalability and reusability being an open standard for all BPMS. A formally complete end-to-end executable processes. Supports transactions with ACID properties within and outside the process.	The process temporal component is not evident in the BPML process definition since it is coded in XML. Since it is a higher level of programming abstraction, it can only be supported in systems of pure BPMS vendors but not by dominant market products, such as IBM's MQServer and Websphere, and Microsoft's BizTalk.
BPEL	The most popular language and does not have any serious competitors in the industry. Have minimal obsolescence risk. Focus on the processes rather than the low-level programming constructs. Subscribes to the web services paradigm.	Has complex syntax and is difficult to implement. Restrictive syntax as it is an incomplete standard, has limited graphical support, cannot support the cycle processes and has not been adopted in the industry. Does not model human involvement in BPs well. Does not have process constructs as it is not possible to express all conceivable BPs and may use in connection with programming language, such as Java. No support for B2B collaboration.
YAWL	Useful for capturing control flow dependencies and resource requirements. A native data handling using XML schema, XQuery and XPath. Offers relatively few constructs.	Complex Interaction with limited software components

6.3 Yet Another Workflow Language (YAWL)

Yet another workflow language (YAWL), which was proposed by academics from the Queensland University of Technology and TU Eindhoven, is a comprehensive workflow execution language based on all workflow patterns. It has rich control flow constructs although it is not technically a standard. YAWL supports for advanced resource allocation policies and supports for the dynamic adaptation of the workflow models via the worklets notion. It is XML-based and supported on an open source software package which contains a graphical editor, engine, and the work list handler. It can handle more control flow constructs than Petri nets [59].

YAWL adds some syntactical elements to Petri nets to capture other workflow patterns, such as simple merge (xor-join), simple choice (xor-split), and multiple choice (or-split). It turned out that several extensions were added to Petri nets during the design of the language, were difficult or even impossible to re-encode back into plain Petri nets. Consequently, the YAWL original formal semantics are identified as a labelled transition system and not in terms of Petri nets. In particular, the YAWL system includes a static analysis tool called WofYAWL. Table 7 compares the different execution standards of BP modelling techniques.

7. Interchange Standards

Interchange standards are used to facilitate data portability, such as BP design portability in different graphic standards across BPMS and different execution standards across different BPMS. In other words, interchange standards are used to translate graphic standards into execution standards and exchange business PMs between different BPMSs. There are two types of interchange standards: the Business Process Definition Meta-Model (BPDM) and the Extensible Mark-up Language (XML) Process Definition Language (XPDL). These two different standards will be explained in the following two subsections.

7.1 Business Process Definition Meta-Model (BPDM)

The Business Process Definition Meta-Model (BPDM) is an XML-based language proposed by the OMG which identifies the concepts, relationships and semantics for exchanging the user models between different business PM techniques and tools. The format of exchange is identified by the XML schema (XSD) and XML for Metadata Interchange (XMI). It was first adopted in July 2007 and finalized in July 2008. It provides the capability to represent and model BPs independent of methodology or notation, thus bringing different approaches together into the cohesive capability. In BPDM, the meta-model feature is an abstraction of the main and common elements found across BPMN, BPEL, WSFL, XLANG, UML and XPDL.

BPMD contains eight packages structured in three different layers: (1) the common abstractions layer; (2) the common behavioural layer; and (3) the orchestration and choreography layer. The common abstraction layer contains two packages to represent the composition model and courses which are the time-wise compositions. The common behavioural layer contains three packages: the happen and change package, simple interaction model and process behaviour package; in order to extend courses to represent the dynamic behaviours as less or more complex time to success the events, activities and state change. The orchestration and choreography layer contains the activity model to represent the orchestrations and the interaction protocol model to represent the choreographies, thus this layer introduces the activity model as the course of the activities performed by the roles [60].

7.2 XML Process Definition Language (XPDL)

The XML process definition language (XPDL) is a format standardized by the Workflow Management Coalition (WfMC) which established the workflow reference model. It is used to interchange BP definitions among different workflow products, i.e., between different business PM tools and management suites. It identifies the XML schema to specify the declarative part of the BP workflow and is designed to exchange the process definition of the workflow BP for the graphical and semantics business PM [61]. It includes elements to hold graphical information and execution elements to run the BP, which is one of the differences between XPDL and BPEL as BPEL only includes execution elements. It is designed to store all BPMN diagram elements, thus it is the XML serialization of BPMN. Table 8 compares different interchange standards of BP modelling techniques.

Table 8: Different Interchange Standards of Business Process Modelling Techniques.

Techniques	Advantages	Disadvantages
BPDM	Offers a globally accepted file format to save the BP definition. The meta-model feature is an abstraction of the main and common elements found across BPMN, BPEL, WSFL, XLANG, UML and XPDL.	The transformation quality is limited by different syntax and structures. The translation from graphic to execution is easier than the translation from execution to graphic.
XPDL	Includes the elements to hold the graphical information and execution elements to run the BP. Offers a globally accepted file format to save the BP definition. Well-accepted and stable technique and has 10 years' history in the industry. Is the XML serialization of BPMN	The transformation quality is limited by different syntax and structures. The translation from graphic to execution is easier than the translation from execution to graphic.

8. Business PM Guidelines

The purpose of business PM guidelines is to assure the PM quality and consistency that are created by different users. The best practices are captured in order to be beneficial to support the users and reader to understand the model. Thus, these business PM guidelines can be formulated as rules to be followed when modelling BPs, such as the modellers require using the less number of elements in the model as possible. We summarize the business PM guidelines in the list below.

- Use less number of elements in the model
- Keep the model structured as possible
- Avoid deadlocks
- Minimize the crossing arcs numbers
- Use clear flow direction (right-left) or (top-bottom)
- Use verb object style for activities
- Use AND & XOR connectors and no OR routing element
- Use different colours for the process models to distinguish the different business PM elements types.

There is different aspects of business PM guidelines, such as formal business PM properties, business PM layout, using business PM elements and using the natural language. The formal business PM properties refer to the correctness of the business PM structure. For example, a good business PM has to be kept as structured as possible and the deadlocks have to be avoided. The business PM layout refers to the proper arrangement of the business PM elements. For example, the good business PM has to minimize the crossing arcs numbers and use a clear flow direction from right to left or from top to bottom in order to make the business PM easy to follow and understand. Using business PM elements identifies which

elements have to be used or not. For example, the elements that have the complicated semantics could be forbidden in order to make the business PM more understandable even by inexperienced business PM users and readers. Using the natural language refers to the terms that can be used in the business PM or the structure that can be used to present these term in label. For example, the good business PM has to use verb object style for activities and forbidden unspecific verbs.

Furthermore, the modellers require using the less number of elements in the model as possible because when the model has large number of elements, it will be hard to understand and may have errors. Also, they have to minimize the element routing path, such as the input and output arcs and only use one start event and one end event in order to avoid errors as well as decomposing models which have more than 50 elements. The model needs to be as structured as possible by matching each spilt connector with the respective join connector within the same type. The literature suggests that using AND & XOR connectors and no OR routing element because AND & XOR may be less error prone.

In addition, business PM is easy to understand if the modellers use verb object activity labels, using different colours for the process models to distinguish the different business PM elements types. Moreover, they should design syntactically and semantically correct models. When the model follows all business PM notation primitive, it will be syntactically correct. The model requires being completed by the real world satiation and acknowledged by the stockholders.

9. Conclusion & Implications

Choosing the right tools and techniques with which to model BPs is very complicated because a large number of techniques have been proposed but there are not as many guidelines to describe the concepts involved. The modeller knows his business, but what he really needs is support in selecting the proper techniques, standards, and languages to accomplish his work. Categorizing the different business PM techniques, tools and standards into different groups with the same functions and characteristics can make logical sense of them.

In this paper, we have presented an overview of the research on the business PM domain. We have categorized the existing business PM techniques and tools into three groups: graphic, execution and interchange standards and have provided a comprehensive analysis on the existing business PM techniques and tools. Then, the graphical standards are divided into graphical standards at enterprise level and graphical standards at process level where graphical standards at enterprise level have been divided into three types: workflow techniques, notation techniques and production techniques. The graphic standards allow the users to state the BPs transitions and flows using diagrams. The execution standards are used to computerize the BPs deployment and automation. The interchange standards are used to facilitate data portability, such as BP design portability in different graphic standards across the BPMS and different execution standards across different BPMS.

In this paper, we have compared different business PM tools, techniques and languages. We proposed a framework to classify the techniques according to their purpose as a guide to practitioners and academics who may need to choose from these techniques. As our proposed literature review methodology presents the advantages and disadvantages for mostly all existing business PM techniques, tools and languages used in the industry, it can help in enhancing manufacturing practice. The manufacturing or business analysts and modellers can review these points according into tables (5-8) and then they will have the right picture what is the most satiable techniques for their cases and requirements. Thus, by selecting the best business PM techniques and tools, the manufacturing and companies' process time, cost and performance can be enhanced. Also, if the manufacturers chose the right techniques, they can easily reengineer their BPs and thus improve their revenue.

There are two main implications can be derived from this paper for business analysts and business modellers. First, for the business analysts have to clearly explain their requirement and define their BPs. Second, for the business modellers, the modellers there is no any right business PM standards or techniques to be used but they should know the purpose of their model in order to select the right business PM techniques and tools.

Further research is required to model a real business process from the business environment, such as a mobile phone order management in the telecommunication company using different business PM techniques and standards in order to understand these techniques in practical way and make it easy to compare between them. Furthermore, one of the possible further researches is to create the guidelines for structuring transfer from one business PM technique into others, such as transfer from UML to BPMN.

References

[1] Sakr, S., Maamar, Z., Awad, A., Benatallah, B., & Van Der Aalst, W. M. (2018). Business process analytics and big data systems: A roadmap to bridge the gap. IEEE Access, 6, 77308-77320.

[2] Tarafdar, M., Cooper, C. L., & Stich, J. F. (2019). The technostress trifecta-techno eustress, techno distress and design: Theoretical directions and an agenda for research. Information Systems Journal, 29(1), 6-42.

[3] Alirezaei, E., & Parsa, S. (2020). Adaptable cross-organizational unstructured business processes via dynamic rule-based semantic network. Information systems frontiers, 22(3), 771-787.

[4] Mamoghli, S., Cassivi, L., & Trudel, S. (2018). Supporting business processes through human and IT factors: a maturity model. Business Process Management Journal.

[5] Alotaibi, Y., & Liu, F. (2012). How to model a secure information system (IS): A case study. International Journal of Information and Education Technology, 2(2), 94.

[6] Ansari, G. A., Hasan, M. M., & Khan, M. N. (2018). UML General Framework for IT Educational Sector: A Critical

Approach for Precise Communication & Analysis. IJCSNS, 18(6), 79.
[7] Rauf, A. (2017). Data flow testing of UML state machine using ant colony algorithm (ACO). International Journal of Computer Science and Network Security, 17(10), 40-44.
[8] Gaebel, J., Schreiber, E., Oeser, A., & Oeltze-Jafra, S. (2018, May). Modular Architecture for Integrated Model-Based Decision Support. In eHealth (pp. 108-115).
[9] Tang, J., Piera, M. A., & Guasch, T. (2016). Coloured Petri net-based traffic collision avoidance system encounter model for the analysis of potential induced collisions. Transportation research part C: emerging technologies, 67, 357-377.
[10] Delaram, J., & Fatahi Valilai, O. (2019). An architectural solution for virtual computer integrated manufacturing systems using ISO standards. Scientia Iranica, 26(6), 3712-3727.
[11] Sun, C. A., Ran, Y., Zheng, C., Liu, H., Towey, D., & Zhang, X. (2018). Fault localisation for WS-BPEL programs based on predicate switching and program slicing. Journal of Systems and Software, 135, 191-204.
[12] Yamamoto, R., Yamamoto, K., Ohashi, K., Inomata, J., & Aoyama, M. (2018). A metamodel-driven business process modeling methodology and its integrated environment for reusing business processes. Journal of Software Engineering and Applications, 11(8), 363-382.
[13] Bistarelli, S., Di Noia, T., Mongiello, M., & Nocera, F. (2017). Pronto: an ontology driven business process mining tool. Procedia computer science, 112, 306-315.
[14] Debnath, N., Salgado, C., Peralta, M., Riesco, D., & Montejano, G. (2010, May). Optimization of the Business Process metrics definition according to the BPDM standard and its formal definition in OCL. In ACS/IEEE International Conference on Computer Systems and Applications-AICCSA 2010 (pp. 1-8). IEEE.
[15] Kueng, P., Bichler, P., Kawalek, P., & Schrefl, M. (1996, August). How to compose an object-oriented business process model?. In Working Conference on Method Engineering (pp. 94-110). Springer, Boston, MA.
[16] Mili, H., Tremblay, G., Jaoude, G. B., Lefebvre, É., Elabed, L., & Boussaidi, G. E. (2010). Business process modeling languages: Sorting through the alphabet soup. ACM Computing Surveys (CSUR), 43(1), 1-56.
[17] Lamine, E., Thabet, R., Sienou, A., Bork, D., Fontanili, F., & Pingaud, H. (2020). BPRIM: An integrated framework for business process management and risk management. Computers in Industry, 117, 103199.
[18] Meidan, A., García-García, J. A., Escalona, M. J., & Ramos, I. (2017). A survey on business processes management suites. Computer Standards & Interfaces, 51, 71-86.
[19] Jung, J., Choi, I., & Song, M. (2007). An integration architecture for knowledge management systems and business process management systems. Computers in industry, 58(1), 21-34.
[20] de Morais, R. M., Kazan, S., de Pádua, S. I. D., & Costa, A. L. (2014). An analysis of BPM lifecycles: from a literature review to a framework proposal. Business Process Management Journal.
[21] Alotaibi, Y. (2016). Business process modelling challenges and solutions: a literature review. Journal of Intelligent Manufacturing, 27(4), 701-723.
[22] Kim, J., So, S., & Lee, Y. (2007). The effects of trust on the intention of adopting business process outsourcing: An empirical study. International Journal of Computer Science and Network Security, 7(10), 118-123.
[23] Lindsay, A., Downs, D., & Lunn, K. (2003). Business processes—attempts to find a definition. Information and software technology, 45(15), 1015-1019.
[24] Alotaibi, Y., & Liu, F. (2016). Business process modelling framework derive and implement IT goals: a case study. International Journal of Industrial and Systems Engineering, 22(2), 161-190.
[25] Aldin, L., & de Cesare, S. (2011). A literature review on business process modelling: new frontiers of reusability. Enterprise Information Systems, 5(3), 359-383.
[26] Alotaibi, Y., & Liu, F. (2017). Survey of business process management: challenges and solutions. Enterprise Information Systems, 11(8), 1119-1153.
[27] Alotaibi, Y. (2020, March). Automated Business Process Modelling for Analyzing Sustainable System Requirements Engineering. In 2020 6th International Conference on Information Management (ICIM) (pp. 157-161). IEEE.
[28] Alotaibi, Y., & Liu, F. (2013, June). Business process modelling towards derive and implement IT goals. In 2013 IEEE 8th Conference on Industrial Electronics and Applications (ICIEA) (pp. 1739-1744). IEEE.
[29] Alotaibi, Y., & Liu, F. (2013). Average waiting time of customers in a new queue system with different classes. Business Process Management Journal.
[30] Alotaibi, Y., & Liu, F. (2014). An empirical study of a novel managing customer power model and business performance in the mobile service industry. Business Process Management Journal.
[31] Tarantilis, C. D., Kiranoudis, C. T., & Theodorakopoulos, N. D. (2008). A Web-based ERP system for business services and supply chain management: Application to real-world process scheduling. European Journal of Operational Research, 187(3), 1310-1326.
[32] Alotaibi, Y. (2016, January). A Secure Business Process Modelling For Better Alignment between Business and IT. In 2016 49th Hawaii International Conference on System Sciences (HICSS) (pp. 4793-4802). IEEE.
[33] Chishti, I., Ma, J., & Knight, B. (2014). Ontology mapping of business process modeling based on formal temporal logic. International Journal of Advanced Computer Science and Applications, 5(7), 95-104.
[34] Vukšić, V. B., Bach, M. P., & Popovič, A. (2013). Supporting performance management with business process management and business intelligence: A case analysis of integration and orchestration. International journal of information management, 33(4), 613-619.
[35] Alotaibi, Y., & Liu, F. (2014). A novel secure business process modeling approach and its impact on business performance. Information Sciences, 277, 375-395.
[36] Alotaibi, Y. (2017). Graphical business process modelling standards, techniques and languages: a literature review. International Journal of Business Information Systems, 25(1), 18-54.
[37] Aguilar-Saven, R. S. (2004). Business process modelling: Review and framework. International Journal of production economics, 90(2), 129-149.
[38] Yang, C. W., Dubinin, V., & Vyatkin, V. (2019). Automatic generation of control flow from requirements for distributed smart grid automation control. IEEE Transactions on Industrial Informatics, 16(1), 403-413.

[39] Goldstein, A., Johanndeiter, T., & Frank, U. (2019). Business process runtime models: towards bridging the gap between design, enactment, and evaluation of business processes. Information Systems and e-Business Management, 17(1), 27-64.
[40] Zhang, H., Liu, W., Xiong, H., & Dong, X. (2018). Analyzing data flow diagrams by combination of formal methods and visualization techniques. Journal of Visual Languages & Computing, 48, 41-51.
[41] Isbal, S., Allen, G., & Mansur, A. (2017). Modelling of Aspects using Aspect-Oriented Design Language. Journal of Theoretical and Applied Information Technology, 95(21), 5711-5722.
[42] Geiger, M., Harrer, S., Lenhard, J., & Wirtz, G. (2018). BPMN 2.0: The state of support and implementation. Future Generation Computer Systems, 80, 250-262.
[43] Amjad, A., Azam, F., Anwar, M. W., Butt, W. H., & Rashid, M. (2018). Event-driven process chain for modeling and verification of business requirements–a systematic literature review. IEEE Access, 6, 9027-9048.
[44] Alotaibi, Y., & Liu, F. (2012, January). Business process modelling towards derivation of information technology goals. In 2012 45th Hawaii International Conference on System Sciences (pp. 4307-4315). IEEE.
[45] Anaya, V., Berio, G., Harzallah, M., Heymans, P., Matulevičius, R., Opdahl, A. L., ... & Verdecho, M. J. (2010). The unified enterprise modelling language—overview and further work. Computers in Industry, 61(2), 99-111.
[46] Matt, D. T. (2014). Adaptation of the value stream mapping approach to the design of lean engineer-to-order production systems. Journal of Manufacturing Technology Management.
[47] Abdmouleh, A., Spadoni, M., & Vernadat, F. (2004). Distributed client/server architecture for CIMOSA-based enterprise components. Computers in industry, 55(3), 239-253.
[48] Lakhoua, M. N., & Khanchel, F. (2011). Overview of the methods of modeling and analyzing for the medical framework. Scientific Research and Essays, 6(19), 3942-3948.
[49] Wortmann, J. C., Hegge, H. M. H., & Goossenaerts, J. B. M. (2001). Understanding enterprise modelling from product modelling. Production Planning & Control, 12(3), 234-244.
[50] IFIP-IFAC Task Force on Architectures for Enterprise Integration. (2003). GERAM: The Generalised Enterprise Reference Architecture and Methodology: Vesion 1.6. 3 (Final). Handbook on enterprise architecture, 21-63.
[51] Shukla, N., Keast, J. E., & Ceglarek, D. (2017). Role activity diagram-based discrete event simulation model for healthcare service delivery processes. International Journal of Systems Science: Operations & Logistics, 4(1), 68-83.
[52] Istiqobudi, K., Saptadi, S., & Rinawati, D. I. (2019). DESAIN SISTEM INFORMASI CREW MANPOWER PLANNING (CMPP) PT. GARUDA INDONESIA TBK. DENGAN INTEGRATED DEFINITION–FUNCTION MODELLING (IDEF0) DAN INTEGRATED DEFINITION–DATA MODELLING (IDEF1X). Industrial Engineering Online Journal, 7(4).
[53] Solaimani, S., & Bouwman, H. (2012). A framework for the alignment of business model and business processes. Business Process Management Journal.
[54] Eisenbart, B., Gericke, K., Blessing, L. T., & McAloone, T. C. (2017). A DSM-based framework for integrated function modelling: concept, application and evaluation. Research in Engineering Design, 28(1), 25-51.
[55] Baruwa, O. T., & Piera, M. A. (2016). A coloured Petri net-based hybrid heuristic search approach to simultaneous scheduling of machines and automated guided vehicles. International Journal of Production Research, 54(16), 4773-4792.
[56] Tbaishat, D. (2018). Process architecture development using Riva and ARIS: comparative study. Business Process Management Journal.
[57] Huang, G. Q., Lau, J. S., & Mak, K. L. (2003). The impacts of sharing production information on supply chain dynamics: a review of the literature. International journal of production research, 41(7), 1483-1517.
[58] Nadarajan, G., & Chen-Burger, Y. H. (2007). Translating a typical business process modelling language to a Web Services Ontology through lightweight mapping. IET software, 1(1), 1-17.
[59] Adams, M., ter Hofstede, A. H., & La Rosa, M. (2011). Open source software for workflow management: the case of YAWL. IEEE software, 28(3), 16-19.
[60] BPDM, O. (2007). Business Process Definition Metamodel (BPDM). Object Management Group.
[61] Van der Aalst, W. M. P. (2003). Don't go with the flow: Web services composition standards exposed. IEEE intelligent systems, 18(1), 72-76.