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A Mini Comparative Study of Requirements Modelling Diagrams towards Swimlane: Evidence of Enterprise Resource Planning System

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Abstract. Model-based requirements engineering (MBRE) is an approach that empowers requirements engineers with adequate models to perform requirements engineering (RE) activities. This approach is increasingly becoming an essential part of system engineering projects as it reduces development time, enhances analysis capability and increases the potential for reuse. Use case diagram, activity diagram, business process management and notation diagram (BPMN) and swimlane diagram are among the diagram used in representing the requirements. However, the swimlane diagram has received little attention in the literature and lack of empirical support, particularly in the requirements engineering field. In this study, a multi-criteria comparative work is performed where three other diagrams are identified and examined against the swimlane diagram. Walkthrough sessions are conducted using enterprise application documents with real users to validate the model-based requirements exemplified using the swimlane diagram. These activities are carried out to highlight the efficacy of the swimlane diagram in representing requirements in the RE field. The results confirmed that the swimlane diagram outperforms NL in overall completion time for the requirement validation process. Furthermore, it gives users a better understanding as they did not need to read textual requirements which are typically ambiguous, confusing, and lengthy.

1. Introduction

Requirements Engineering (RE) is defined as a set of processes involved in developing system requirements; starting from requirements elicitation, requirements analysis, requirements negotiation and requirements validation [1]. RE is the crucial stage in the software development life cycle (SDLC) and should be rigorously performed to build quality and reliable software [2,3]. Typically, the requirements are elicited from various sources and embodied in natural language (NL) and recorded as textual requirements [4]. However, NL has several limitations as it can be interpreted differently by the stakeholder and making requirements engineering activities difficult, fault-prone and challenging tasks [2]. Although many fault-based infection techniques such as Walkthrough, Consistency Checking and Linguistics Analysis have been taken to improve the quality of requirements specification written in NL, there is still colossal effort spent on fixing the requirements problems which should be fixed early in SDLC stage [2,5–7]. Hence, a practical way to help improve the NL requirements is by using a model-based approach [8].



Model-based requirements engineering (MBRE) is the model-based approach that empowers requirements engineer with adequate models to perform RE activities. This approach is increasingly becoming essential of the systems engineering because it can reduce development time, enhance analysis capability, increase the potential for reuse and facilitate communication with users [9–11]. MBRE helps requirements engineers to address and communicate the requirements with the stakeholders [11]. There are a few diagrams associated with the MBRE such as Business Process Model and Notation (BPMN) [12], swimlane diagram, and Systems Modelling Language (SysML) diagrams including use case, sequence, activity and state-machine diagrams [13].

Use case diagram is designed to model system context (i.e., functions) but not the business process [13]. It provides a high-level description of system functionality. On the other hand, the sequence diagram emphasises logical timing of interactions (messages) between system elements or functions which normally interpreted using use-case diagram [13,14]. State-machine expresses the state transitions and actions of the system or part of the system in response to events [13,15] and useful to study the impact of modularity on process model understandability [16]. Consequently, activity diagram [12,13,17,18] and BPMN [12,17,19–21] are designed for business process modelling. Both diagrams characterise system functionalities and illustrate the relationships between business processes in a workflow process manner.

Swimlane diagram or cross-functional flowchart is conceived for business process modelling [11,22]. The diagram has been utilised mainly in requirements engineering of software development activities, including in several other domains such as transportation, enterprise application, and safety-critical system, and academic library [23–26]. It is a type of chart which shows the series of process steps connected by the arrows to depict their order and applies “swim lane” to provide extra dimensions with means of assigning each process step to a particular category. [26] proposed the use of swimlane diagrams as a diagram to depict the Academic Library process flow. Although [27–32] mentioned the swimlane diagram, the studies referred to swimlane elements that embody the participants of business processes in pools and lanes in BPMN and activity diagram. It is beneficial to depict complex processes that require multiple attributes or several people (e.g., intra and inter-department process connectivity) in a simple flowchart, especially for enterprise applications [25]. While software development is refined these days, this chart deems useful to assist in determining their unique needs for mobile application development and practical for model-based testing, accordingly [24,31]. There was an attempt to conducted an empirical evaluation to examine the efficacy of the swimlane diagram; however, the study relies only on a quantitative approach that may be biased [11].

The main objective of this study is to investigate the efficiency of swimlane diagrams by initially conducting a comparative study of three diagrams against the swimlane. The comparison was accomplished by analysing the diagrams using several essential criteria. Next, a further investigation of time factor (i.e., the completion time for the validation process) was carried out applying the data of several sub-systems of Enterprise Resource Planning System. Finally, the study presents and discusses the findings following the outlined research design.

2. Methodology

2.1. Research Design

In order to highlight the efficacy of the swimlane diagram in representing requirements, two activities were conducted, as shown in Figure 1. Firstly, a comparative study of diagrams that consists of various activities started from the selection of diagrams, comparative study of the identified diagrams and result and analysis of the study. Next, the walkthrough which was conducted with the involvement of users and it consists of a sequence of activities which includes setting up of the objective of the walkthrough, identification of users, preparation of data and session plan. Result and analysis were discussed after the completion of walkthrough sessions.

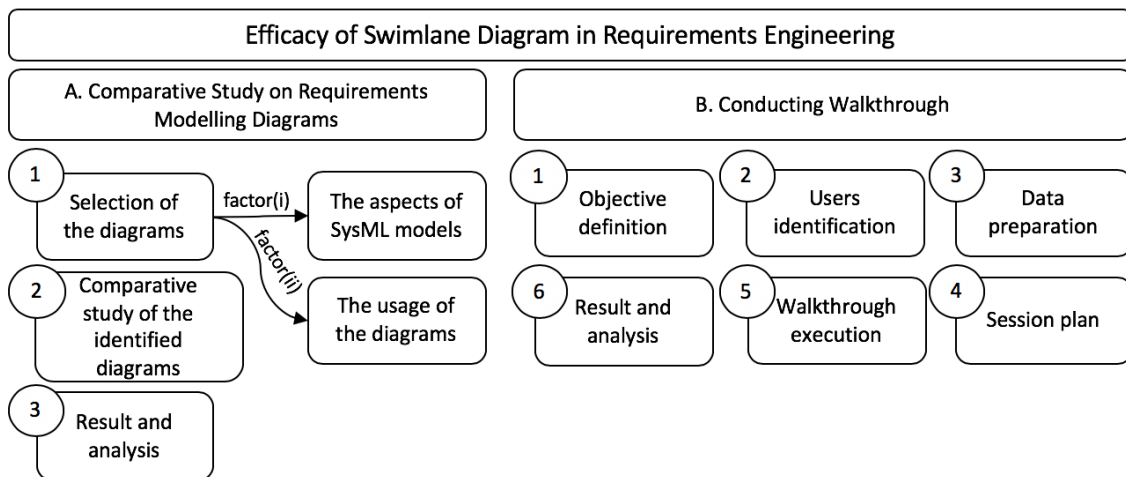


Figure 1. Research activities.

2.2. Comparative study of the identified diagrams

In this study, the swimlane and three other diagrams were selected for comparison. The selection was conducted based on the factors of 1) the aspects of the SysML model, 2) the usage of the model. The first factor is on the aspects of the SysML model, which defined the system. There are two aspects of SysML, which are the structural and behavioural aspects [13]. The structural aspect of the model explains what the system looks like and what it does, symbolises by the block definition diagram, package diagram, internal block diagram, parametric diagram and requirements diagram [13].

The behavioural aspect of the model defines how the system behaves, its conditions and interactions between and within the system elements. This aspect is commonly demonstrated in use case, activity, sequence and state-machine diagrams [13]. Comparatively, by taking these diagrams and swimlane diagram into consideration, it has been found that swimlane diagram realises a behavioural aspect of a model as it has similarity with the activity diagram. Therefore, the SysML behavioural diagrams were selected to be compared with the swimlane diagram. BPMN was also selected as it has similarity with the activity diagram. Next, the study brings the usage of each diagram into deliberation. Swimlane diagram, activity diagram and BPMN are designed for business process modelling and able to describe the system functionality. Use case diagram is not intended for business process modelling but able to describe system functionality. Meanwhile, the sequence diagram and state-machine diagram are also not designed for business process modelling nor system functionality. From these five behavioural diagrams, only three were selected to compare against the swimlane diagram, including activity, BPMN and use case diagrams. The selection was made due to their ability to describe the system functionality. However, sequence and state-machine diagrams were excluded in consequence of their inability to describe system functionality.

Table 1 and Table 2 show the comparison of four diagrams based on specific criteria such as their primary goal, purpose, level of abstraction, categories of elements and notation. It can be recognised that BPMN, swimlane, activity diagrams show similarities in many criteria such as their goal and purposes, categories of elements, workflow pattern and resource pattern. Swimlane diagram, activity diagram and BPMN are designed for business process modelling, and they have more than four categories of elements that can describe the activity in a workflow process. These three diagrams can also describe the distribution of work to the resources and the management of work by using lane and pools.

Even though the use case diagram falls within the same category of the model-based, it is not designed for business process modelling. It models system context or the highest level of abstraction. Furthermore, it has a limitation in describing activity in a workflow process. It also did not apply any resource pattern in which there is no lane and pools pattern in the use case diagram.

	Swimlane Diagram	Business Process Management Notation	Activity Diagram	Use Case Diagram
Similarity	Model-based Diagram			
	Designed for business process modelling			
	Have more than 4 categories of elements			
	Elements describe the activity in a workflow process			
Difference	Describe the distribution of work to the resources and management of work by using lane and pool			
	Less studies manipulated swimlane diagram	Many studies exploiting BPMN and activity diagram		Not designed for business process modelling
				It is designed to model system context or the highest level of abstraction that available in the SysML
				Has 5 categories of elements
			Not described activity in a workflow process	
			Did not apply any resource pattern in which there is no lane and pools pattern	

Figure 2. Summary of similarities and differences among related diagrams.

Figure 2 summarises the similarities and differences of the identified diagrams. It can be seen that there are many research [12,17,31,32,18–21,27–30] has been conducted to BPMN and activity diagram. However, there is less research [11,26] has been conducted to the swimlane diagram even though it has similarities in many aspects with the other diagrams. Besides, only [11] provides an empirical evaluation of swimlane diagram. Therefore, it is an opportunity to utilise the swimlane diagram as one of the diagrams to represent not the only business process but also functional requirements.

2.3. Validating the model-based requirements thru walkthrough

A walkthrough is one of the reliable types of review or manual validation techniques used to validate requirements [33]. Walkthrough aims to identify quality flaws within requirement and to gain an understanding of the requirements between stakeholders [33].

In this study, the walkthrough was conducted to validate the requirements collected for an integrated system-to-be that consists of five sub-systems of an Enterprise Resource Planning system. The sub-systems are Loan Management System, Premise Management System, Training Management System, Project Monitoring and Budget Monitoring.

Prior to the sessions, objectives, user involvement and the Functional Design Document (FDD) have been clearly defined and identified. The users were informed about the types of data and verification activities they should perform. They were classified according to the departments and sub-systems assigned to them during the requirements elicitation stage. The FDDs contains requirements to be validated, which are denoted using swimlane diagrams, as shown in Figure 3.

For each walkthrough, the requirements were discussed with the guidance of the requirements' author and minute-taker recorded identified flaws during the session. Consequently, other team members involved in the session assisted in amending the swimlane diagrams based on comments received from the users.

Besides identifying the flaws within requirements, this walkthrough also examined the efficacy of the swimlane diagram in representing the requirements. The efficacy was observed based on their understanding of the requirements and time taken to complete the validation process. The estimated time to complete the validation process was set up by an experienced project management team adopting their experience if NL requirements were in use.

Table 1. Comparison among swimlane diagram, activity diagram, BPMN and use case diagram.

Criteria \ Diagrams	Swimlane Diagram	Activity Diagram	Business Process Management Notation	Use Case Diagram
Primary goal	<ul style="list-style-type: none"> • can be used for business process modelling • shows a list of processes linked by the arrows to indicate their sequence • applies swim lane that provides an extra dimension that assigns each process to a specific category • shows complex processes that require multiple attributes or people in a simple flowchart 	<ul style="list-style-type: none"> • can be used for business process modelling • elements can be used for various purposes • straightforward and easy to read the diagram • show flow of control and data flow 	<ul style="list-style-type: none"> • makes ease of business process modelling • reduces the gap between technical and business users. • understandable by all stakeholders 	<ul style="list-style-type: none"> • realises a behavioural aspect of a model, with an emphasis on functionality rather than the control and logical timing of the system. • represents the highest level of abstraction in the SysML
Purpose / Usage	Use to model: <ul style="list-style-type: none"> • business processes • relationships between the business processes and the functional units responsible for the processes. 	Use to model: <ul style="list-style-type: none"> • business processes • flow within the use case • business rules logic • functional processes • User Interface (UI) screen flows 	Use to model business process only	Use to model system context
Level of abstraction	No	No	Three levels of abstraction <ul style="list-style-type: none"> • a Private business process • a Public business process • a Global business process 	No
Categories of elements	Four categories of elements <ul style="list-style-type: none"> • swimlanes • connector • Shapes (Basic flowchart shapes) • Phases 	Five categories of element <ul style="list-style-type: none"> • Actions • Sub-activities • Data objects • Control nodes • Partition 	Four categories of elements <ul style="list-style-type: none"> • flow objects • connecting objects • swimlanes • artefacts 	Four categories of elements <ul style="list-style-type: none"> • use cases • actor • relationships • system boundary

Table 2. Comparison among swimlane diagram, activity diagram, BPMN and use case diagram.

Criteria	Diagrams				
		Swimlane Diagram	Activity Diagram	Business Process Management Notation	Use Case
Item	Notation	Yes	Yes	Yes	No
Control flow patterns - describe the flow of control in the	Basic control flow pattern: Sequence (An activity in a workflow process is enabled after the completion of another activity in the same process)	Yes	Yes	Yes	No
	Advanced patterns: State-based patterns (Each activity in the set is executed, the order is decided at run time, and no two activities are executed at the same time)	No	Yes	No	No
Data patterns - describe patterns that are related to data and data objects	Data visibility patterns - Case data (Data elements are supported which are specific to a process instance or case of a workflow. All components of the workflow can access them during the execution of the case)	No	Yes	No	Yes
	Data visibility patterns - Workflow data (Data elements are supported and are within the control of the workflow system)	Yes	No	Yes	No
	External data interaction (If data should be stored in a database which is an external process and not part of the workflow - it can be modelled)	No	Yes	No	Yes
Resource patterns - describe the distribution of work to the resources and the management of the work.	lanes and pools	lanes and pools	lanes and pools	No	

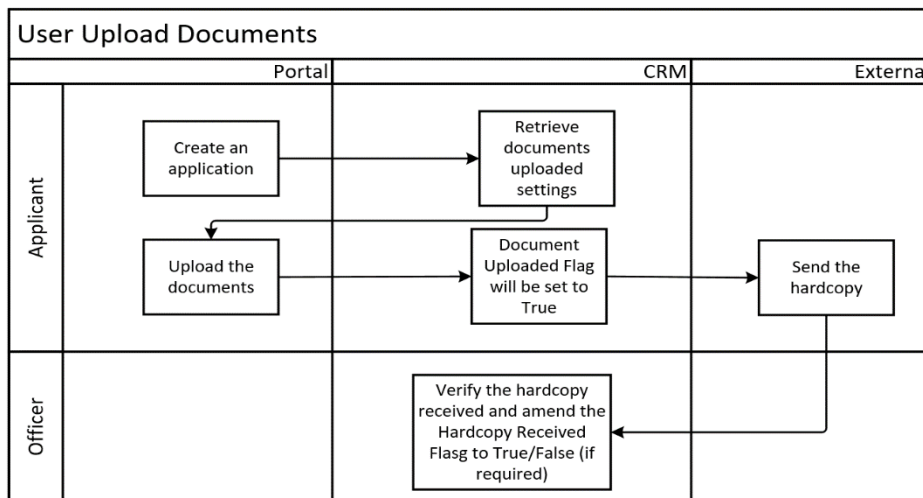


Figure 3. An example of the swimlane diagram used in the walkthrough.

Table 3 lists sessions conducted, which leads to the following findings:

- Overall requirements validation completion time was reduced by 15.2% as opposed to the planned time if NL requirements are in place because users have a better understanding of the business or system processes as they did not need to read lengthy textual requirements.
- Users were able to validate the business or system processes efficiently when they are modelled using the swimlane diagram due to step by steps processes accompanied with appropriate sequence numbers.
- Any amendments of the requirements can be performed instantly and re-present to the users with less lead time.

Table 3. Result for the requirements validation process.

Systems	Number of Documents	Number of Swimlane diagrams	Number of Participants	Sessions	Estimated time	Actual completion time	Time difference
a	10	37	24	Session 1	3 hours	4 hours	-1 hour
				Session 2	3 hours	1 hour	2 hours
b	3	7	7	Session 1	5 hours	3.5 hours	1.5 hours
c	9	26	10	Session 1	5 hours	5 hours	0 hour
d	1	14	22	Session 1	1 hour	1 hour	35 minutes
				Session 2	1 hour	45 minutes	15 minutes
				Session 3	1 hour	40 minutes	20 minutes
e	1	10	22	Session 1	1 hour	1 hour	0 hour
				Session 2	1 hour	45 minutes	15 minutes
				Session 3	1 hour	1 hour	0 hour
Total Hours					22 hours	18 hours 40 minutes	3 hours 20 minutes
Total Hours (%)					100%	84.8%	15.2%

^a Loan Management System [34]

^b Premise Management System [35]

^c Training Management System [36]

^d Project Monitoring [37]

^e Budget Monitoring [38]

3. Conclusion

Research in the model-based approach for RE has been scattered in several domains and aspects in the literature. The swimlane, a kind of diagram that supports the approach, has many advantages in drawing business process. Having said that, the sparsity of research in this area makes the swimlane diagram a bit left out despite its ability to model business processes effectively and efficiently. Although there is a general perception which organisation and business process can be adequately validated by virtue of its nature, however, insufficient evidence is found in the literature focusing on RE.

This study aims to highlight the efficacy of the swimlane diagram by first conducting a comparative study of three diagrams against the swimlane. The comparison was performed by analysing the diagrams using several essential criteria such as primary goal, purpose, level of abstraction, categories of elements and notation. Then, a further investigation of time factor was carried out using the walkthrough technique by applying the data of several sub-systems of Enterprise Resource Planning related to Loan, Premise, and Training Management, as well as Project and Budget Monitoring.

The results confirmed that the swimlane diagram outperforms NL in overall completion time for the requirement validation process. The swimlane diagram also helps users to have a better understanding of requirements and ease users in validating the requirements as they do not need to read lengthy textual requirements. These findings suggest that in general, swimlane diagram able to help requirements engineers to amend the requirements according to the user comments, and it can be done instantly during the session. The scope of this study was limited in terms of generalising the findings towards other types of software systems, although it has significant potential to represent the business process and functional requirements for such purpose. A natural progression of this work is to explore the approach for extracting software features from model-based requirements that delineated using the swimlane diagram.

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References

- [1] Kotonya G and Sommerville I 1998 Requirements engineering: processes and techniques 282
- [2] Aceituna D, Do H, Walia G S and Lee S W 2011 Evaluating the use of model-based requirements verification method: A feasibility study *Proc. - 1st Int. Work. Empir. Requir. Eng. Emp. 2011* 13–20
- [3] Abu Bakar N W, Mohamad A H, Jatavakabhulla P K and Musa S 2018 Effect of Lean Systematic Method on Specimen Handling Activities for Patients in Medical Wards *International Journal of Engineering & Technology* vol 5 pp 134–9
- [4] Aysolmaz B, Leopold H, Reijers H A and Demirörs O 2018 A semi-automated approach for generating natural language requirements documents based on business process models *Inf. Softw. Technol.* **93** 14–29
- [5] Heitmeyer C L, Jeffords R D and Labaw B G 1996 Automated Consistency Checking of Requirements Specifications **5** 231–61
- [6] Chantree F and Roeck A De 2006 Identifying Nocuous Ambiguities in Natural Language Requirements
- [7] Brykczynski B 1999 A Survey of Software Inspection Checklists *ACM SIGSOFT Softw. Eng. Notes* **24** 82–9
- [8] Kof L, Gacitua R, Rouncefield M and Sawyer P 2010 Ontology and Model Alignment as a Means for Requirements Validation
- [9] Holt J, Perry S, Brownsword M, Cancila D, Hallerstedde S and Hansen F O 2012 Model-based requirements engineering for system of systems *Proc. - 2012 7th Int. Conf. Syst. Syst. Eng. SoSE 2012* 561–6

- [10] Holt J, Perry S, Payne R, Bryans J, Hallerstede S and Hansen F O 2015 A Model-Based Approach for Requirements Engineering for Systems of Systems **9** 252–62
- [11] Jeyaraj A, Sauter V L and St M 2014 Validation of Business Process Models Using Swimlane Diagrams *J. Inf. Technol. Manag.* **XXV** 27–37
- [12] Peixoto D C C, Batista V A, Atayde A P and Borges E P A Comparison of BPMN and UML 2 .0 Activity Diagrams **3** 1–14
- [13] Holt J, Perry S A and Brownsword M 2012 *Model-Based Requirements Engineering*
- [14] Campean F and Yildirim U 2017 Enhanced Sequence Diagram for Function Modelling of Complex Systems *Procedia CIRP* **60** 273–8
- [15] Damjan P and Vatanawood W 2017 Translating UML State Machine Diagram into Promela *Proc. Int. MultiConference Eng. Comput. Sci. 2017 I*
- [16] Dikici A, Turetken O and Demirors O 2018 Factors influencing the understandability of process models: A systematic literature review *Inf. Softw. Technol.* **93** 112–29
- [17] Eloranta L, Kallio E and Terho I 2007 A Notation Evaluation of BPMN and UML Activity Diagrams
- [18] Eriksson H-E and Penker M 2000 *Business Modeling with UML: Business Patterns and Business Objects* (Wiley & Sons)
- [19] Taylor P, Aldin L and Cesare S De 2011 A literature review on business process modelling : new frontiers of reusability 37–41
- [20] Model B P 2017 Business Process Model and Notation 1–16
- [21] Birkmeier D Q 2009 Quality Marks , Metrics , and Measurement Procedures for Business Process Models The 3QM-Framework 208–9
- [22] Bandor M 2007 Process and Procedure
- [23] Alter S 2015 Work System Theory as a Platform *J. Assoc. Inf. Syst.* **16** 485–514
- [24] Shibayama T 2017 Organizational structures of urban public transport - a diagrammatic comparison with UML *Transp. Res. Procedia* **25** 3674–93
- [25] Nnamdi M C 2016 *Enhancing enterprise resource planning and manufacturing execution system efficiency with simulation-based decision support*
- [26] Ornat N and Moorefield R 2019 Library Cartography : Mapping Workflow Processes in an Academic Library Library Cartography : Mapping Workflow Processes in an Academic Library **0826**
- [27] Matulevičius R, Norta A and Samarūtel S 2018 Security Requirements Elicitation from Airline Turnaround Processes *Bus. Inf. Syst. Eng.* **60** 3–20
- [28] Wi P 2019 applied sciences Spreadsheets as Interoperability Solution for Business Process Representation
- [29] Yue T, Briand L C and Labiche Y 2015 aToucan: An automated framework to derive UML analysis models from use case models *ACM Trans. Softw. Eng. Methodol.* **24**
- [30] Argyropoulos N 2018 *Designing Secure Business Processes from Organisational Goal Models*
- [31] Buchmann R A and Karagiannis D 2017 Modelling mobile app requirements for semantic traceability *Requir. Eng.* **22** 41–75
- [32] Al-Alshuhai A and Siewe F 2015 An extension of UML activity diagram to model the behaviour of context-aware systems *Proceedings - 15th IEEE International Conference on Computer and Information Technology, CIT 2015, 14th IEEE International Conference on Ubiquitous Computing and Communications, IUCC 2015, 13th IEEE International Conference on Dependable, Autonomic and Se* pp 431–7
- [33] Pohl K and Rupp C 2014 *Requirements Engineering Fundamentals: A Study Guide for the Certified Professional for Requirements Engineering Exam Foundation Level/IREB compliant*
- [34] UniKL Resources 2016 *Functional Design Document: Loan Management System*
- [35] UniKL Resources 2016 *Functional Design Document: Premise Management System*
- [36] UniKL Resources 2016 *Functional Design Document: Training Management System*
- [37] UniKL Resources 2016 *Functional Design Document: Project Monitoring*
- [38] UniKL Resources 2016 *Functional Design Document: Budget Monitoring*