Using Enhanced IDEF-SIM (EnIS) Technique to Model Sustainable Supply Chains (SSCs) (Part I)

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Abstract

A Sustainable Supply Chain (SSC) is required to consider Environmental, Economic and Societal needs equally and in tandem. SSCs are super systems that is made up of multiple interconnected forward and reverse business processes which relays and relies on resources and information from one another. There are only a few techniques that are able to model such complex relationship, and among the best is the IDEF family of techniques. There are also variations to these core techniques which specifically model End-of-Life Vehicle (ELV) recovery, and there is also a hybrid technique which allows a single IDEF technique is used for modeling, instead of using a number of complementing techniques which is the norm. In this study, these two variation techniques are merged and further refined to allow it to model sustainability elements which was missing in any core technique or its variation. This proposed technique is called Enhanced IDEF-SIM (EnIS) and will provide a novel way to model and understand the infrastructure of complete SSCs.

Keywords: IDEF Technique; Sustainable Supply Chain; Enhanced IDEF-SIM

1.0 INTRODUCTION

A comparative study by Ahi and Searcy (2013) on the differences between Green Supply Chain (GSC) and Sustainable Supply Chain (SSC) popular definitions has found that GSC definitions have environmental thinking and ecological efficiency as common keywords; whilst SSC definitions have concern for the environment, concern for profitability, concern for society, and strategic management as its common keywords. This is not surprising as SSCs are supply chains that applies the concept of sustainable development into its management system, and in doing so requires its business processes to balance the needs of the environment, society, and its own economic concerns in tandem. Modeling a super system such as this will be complex due to the relationship of these three interconnecting needs, plus the configuration of the supply chain tends to be closed looped as it encompasses the entirety of a product's life.

2.0 EXISTING BUSINESS PROCESS MODELLING TECHNIQUES

Based on the study made by Aguilar-Saven (2004), the most popular method to model business processes is the IDEF0 technique, which is one of the 14 unique techniques belonging to the Integrated Computer Aided Manufacturing Definition (IDEF) family of techniques. Each of these techniques is made unique in order to effectively address a specific problem type (Mayer et al, 1992). This also means that a number of these techniques are used together in order to model complex governmental and commercial business systems (Menzel and Mayer, 2006). However, even when used together there exist gaps, especially in the inability to model agents (social actors and roles) and no direct mean to validate or verify the results (Jeong et al, 2009). Furthermore, the top-down dissection approach in systems analysis used by the IDEF0 technique is seen to be inadequate when used to model sustainable supply chain business processes such as the End-of-Life Vehicles (ELVs) recovery, prompting the development of its variation which is identified as Enhanced IDEF0 (Wang et al, 2011a, 2011b).

There is also a variation called the IDEF-Simulation (IDEF–SIM) technique which was developed by Montevechi et al (2010), with its main characteristic being the similarity of its application logic with the logic used in Discrete Event Simulation (DES). They further reported that the technique would be most useful when applied in two different moments of a simulation project – (1) Conceptual Modelling Phase; and (2) Model Documenting Phase (used to register the logic of the model, not only facilitating the task of verification and validation – a task not possible when using IDEF0, IDEF1X or IDEF3). An application of IDEF-SIM for the use in Model Documenting phase can be found in the work of Rangel and Nunes (2011) where they have successfully model the unloading of coal at Ferry Terminal Ponta Ubu – Samarco – ES in Brazil before interpreting the model in the simulation software Arena® 12. Even though IDEF-SIM is an efficient technique to model systems, it is still not sufficient to model sustainable systems. The Enhanced IDEF0 technique variation on the other hand, is sufficient to model sustainable systems but requires additional IDEF techniques to complement it, making it inefficient to model complex super systems such as the SSC.

3.0 ENHANCED IDEF-SIM (EnIS) TECHNIQUE

In order to address the gaps found in both the IDEF-SIM and the Enhanced IDEF0 techniques, it is proposed that these two techniques be integrated into a new variation. This new proposed technique is identified as the Enhanced IDEF-SIM (EnIS) technique and integrates sustainability system modelling capability of the Enhanced IDEF0 technique with the simulation assisting ability and documentation efficiency of the IDEF-SIM technique. It also improves the junction rule schematics and definitions used by its predecessors. For instance, in the IDEF-SIM technique, the IDEF3 rules for XOR, Synchronous AND, and Synchronous OR were left out, plus IDEF-SIM uses a different definition for the OR rule. As the real power of IDEF3 lies in its ability to represent processes in which multiple parallel and alternative threads are woven together into a single complex whole (Mayer et al, 1995), it is therefore necessary for EnIS to make use of all IDEF3 rulings instead of the ones used in the IDEF-SIM technique. However, in order to make the model more universally understood by users not familiar with IDEF3, the schematics for the OR and Exclusive OR rules for EnIS follows the IEC 60617-12:1997 Schematic Standards (1997) instead of the ones used by IDEF3. The Synchronous OR schematic on the other hand is a merge between IDEF3 and the IEC60617-12:1997 Schematic Standards (1997) on the Synchronous OR rule schematic and OR rule schematic respectively. However, since the AND rule schematic used by IDEF3 is already similar to the one used by the IEC60617-12:1997 Schematic Standards (1997), it will continue be used in the EnIS technique.

Besides the superiority in ruling, the EnIS technique is also able to model if an entity from the modelled environment flows out of the system boundaries. In a sustainable supply chain environment, products are recovered after use thus prompting the use of closed looped supply chain configurations. However, even in a closed looped system such as this, entities still need to flow from outside of the system into it, and from inside the system to outside. In IDEF-SIM, only schematics for entities not created in the system boundaries flowing into the model is represented, whilst there are no schematics used to model entities flowing out of the model boundaries and into the Open System environment. Therefore, the schematics proposed by the EnIS technique to address this issue is necessary, especially for complex SSC systems such as the Sustainable Supply Chain for Vehicles (SSCV). In a SSCV where End-of-Life Vehicles (ELVs) are collected, the resulting materials recovered from these ELVs will be recycled. These recycled materials does not return only as materials for new vehicles, but instead will be used in all industries which requires the material. This relationship is possible to be modelled using the EnIS technique, where the Recycled Material entity will be modeled to flow into a Synchronous OR junction, with one of the output paths flowing out of the SSCV system boundaries.

The EnIS technique also differs from its predecessors in terms of its definition to Control and Mechanism factors. Control Factors are categorized as Economical, Environmental and

Legislative control factors in the Enhanced IDEF0 technique, whilst the IDEF-SIM technique uses a general "Control Rules" term. Mechanism factors on the other hand are categorized as Technology, Equipment and Processes by the Enhanced IDEF0 technique, and is defined by the IDEF-SIM technique as resources needed to execute the modeled activity. In the EnIS technique, there are only two control factors considered which are the Legislative Control factors, and the Non-Legislative Control factors. Each control factor contains its own set of Environmental, Societal, and Economic needs. For instance, the control factors contain within the Legislative Control embodies legal acts and regulations that are exposed to the business process; whilst Non-Legislative Control factors considers non-legal requirements such as Financial Targets, Key Performance Indices, and Corporate Social Responsibilities. "Technical Control" is not considered as a direct Control factor in the EnIS technique as elements of it can be modelled to be part of the Non-Legislative Control factor.

Mechanism factors used by the EnIS technique are given as Equipment, Budget and Human Capital. Unlike the Enhanced IDEF0 technique, "Technology" is not considered as a direct Mechanism factor as elements of technology can be modelled inside the "Equipment" or the "Human Capital" factors. Furthermore, the demand or creation of a new technology related to a business process can be modelled using the EnIS technique as an "Information and Documentation Entity". For instance, the demand for a new manufacturing technology will be created in the Manufacturing business process as an "Information and Documentation Entity" and will flow into the Research business process, where the resulting new manufacturing technology will be created – either as an "Information and Documentation Entity" if it is knowledge related, or as a "Material and Product Entity" – and flows back to the Manufacturing business process. "Budget" on the other hand, must be considered as a direct Mechanism since a business process requires it to perform operations or activities and when making capital investments. "Human Capital" too must be considered as a direct "Mechanism" factor since it includes societal aspects into the technique by considering Worker Skills and Worker Education as part of the mechanism that is required to run the business process. Table 1 lists the main differences between the schematics and its respective definitions between the Enhanced IDEF0 technique, the IDEF-SIM technique, and the Enhanced IDEF-SIM technique.

4.0 CONCLUSION

In order to model sustainability elements that are required in SSCs, a specific IDEF technique variation that is able to model this requirement is needed. The current technique variation known as the Enhanced IDEF0 and the IDEF-SIM techniques may provide some solution in addressing the issue but there are gaps in these techniques. Recognizing this gap, a new IDEF technique variation was proposed which merges the two. The resulting technique is further refined and enhanced in order to make it a superior technique to its predecessors. This proposed technique is known as the Enhanced IDEF-SIM (EnIS) technique and is shown to be superior to its predecessors in terms of its rulings and schematics.

References

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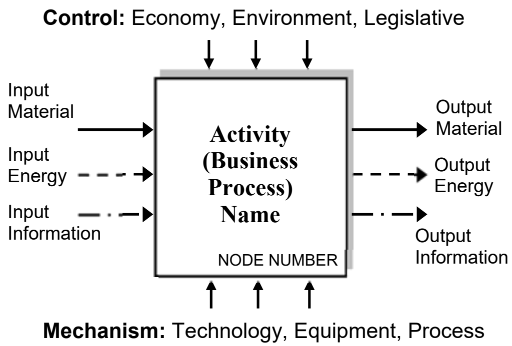
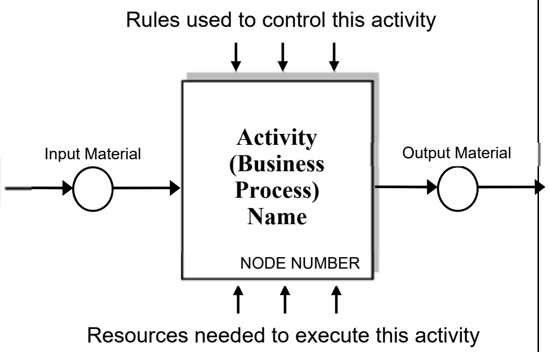
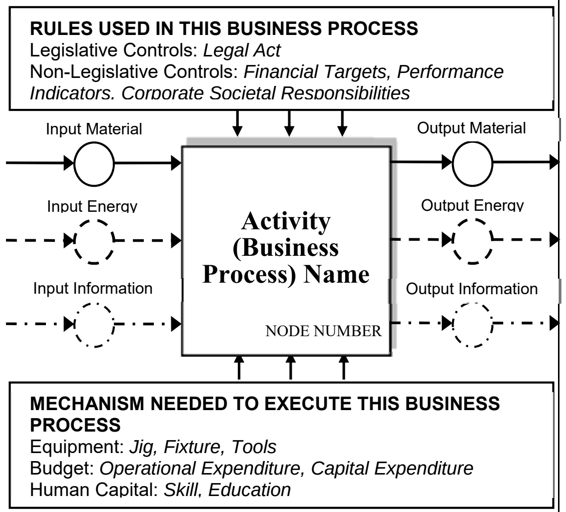
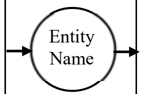
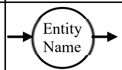
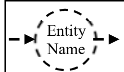
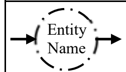
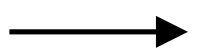
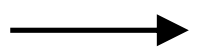
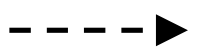
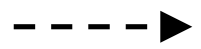
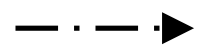
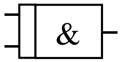
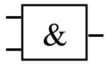
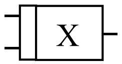
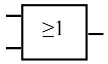
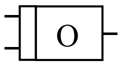
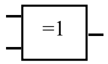
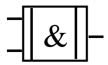
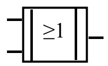
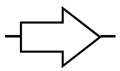
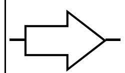
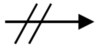
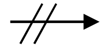
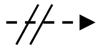
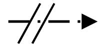
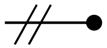
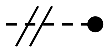
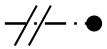
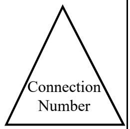
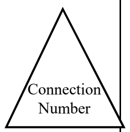
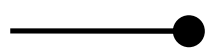
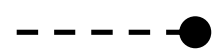
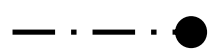
Table 1. Comparison between Enhanced IDEF0, IDEF-SIM and Enhanced IDEF-SIM

	Enhanced IDEF0		IDEF-Simulation (IDEF-SIM)		Enhanced IDEF-SIM (EnIS)	
Technique Overview						
Entity - Items to be processed in the system - Shown at point of creation	*Does not use any schematics to represent items created (entity)*			Single Entity schematic used to represent raw material, products, people, documents		Schematic to represent Material and Product Entity
						Schematic to represent Energy Entity
						Schematic to represent Information and Document Entity
Entity Flow - Represent direction - Characterizes moment of input and output		*Not entity flow schematic. This is used to represent material flow*		Single Entity Flow schematic used		Schematic to represent Material and Product Entity flow
		*Not entity flow schematic. This is used to represent energy flow*				Schematic to represent Energy Entity flow
		*Not entity flow schematic. This is used to represent information flow*				Schematic to represent Information and Document Entity flow

Rules for parallel and/or alternative flows	*Does not use such rules. However,* *- Uses Forking and Joining Arrows to represent branching of paths/flows* *- When Output Flow enters next few business processes/activities as Control, it represents synchronous/concurrent activity*		AND Rule Schematic. Used to represent junction where two or more paths can be executed together - IDEF3 uses same schematics		AND Rule Schematic. Used to represent junction where two or more paths can be executed together. - IDEF3 has similar rules - Follows IEC 60617-12:1997 schematics
			OR Rule Schematic. Used to represent junction where there is an alternative route - IDEF3 does not use this symbol to represent OR Rule		OR Rule Schematic. Used to represent junction where a minimum of one path/flow can pass through. - IDEF3 has similar rules - Follows IEC 60617-12:1997 schematics
			AND/OR Rule Schematic. Used to represent junction where either AND or OR rule can be used - IDEF3 does not have this rule		EXCLUSIVE OR Rule Schematic. Used to represent junction where only one path/flow can pass at a single time. - IDEF3 has similar rules - Follows IEC 60617-12:1997 schematics
					SYNCHRONOUS AND Rule Schematic. Used to represent junction where two or more paths MUST be executed together. - IDEF3 has similar rules - Mimics IDEF3 schematics
					SYNCHRONOUS OR Rule Schematic. Used to represent junction where a minimum of one path/flow can pass through SIMULTANEOUSLY. - IDEF3 has similar rules - Mimics IDEF3 schematics
Motion - Possess important effect on system	*Does not use such rules*		Represents Entity displacement		Represents ONLY Material and Product Entity displacement

Connection with entities beyond system boundaries	*Does not use such rules*		Main input or the creation of entities (for entities not created in the model)		Material and Product Entity input from beyond system boundaries (e.g. Minerals)
					Energy Entity input from beyond system boundaries
					Information and Document Entity input from beyond system boundaries
					Material and Product Entity flows out of system boundaries
					Energy Entity flows out of system boundaries
					Information and Document Entity flows out of system boundaries

Connection within system boundaries	*Does not use such rules*		Used to divide the model
			- Used in pairs
			- Possible uses (due to long path or to tidy up diagram):
			  - breaks input or output flows
			  - breaks output to input flow
			- Not possible to use on input to output flow since all input needs to go through a business process/activity before continuing to flow as output
					Used to divide the model
					- Used in pairs
					- Possible uses (due to long path or to tidy up diagram):
					  - breaks input or output flows
					  - breaks output to input flow
					- Not possible to use on input to output flow since all input needs to go through a business process/activity before continuing to flow as output

End of Flow - Everything found beyond this point is out of the limits of the model.	*Does not use such rules*		End of a path inside modelled flow.		End of a Material and Product Entity path inside a modelled flow.
					End of an Energy Entity path inside a modelled flow.
					End of an Information and Document Entity path inside a modelled flow.