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Build-To-Order Requirements Model of the Automotive Supply Chain via Systems Engineering Concept

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Abstract

The Moroccan automotive industry is in continued development and remarkable growth, because of the progressive OEMs (Original Equipment Manufacturers) number installed in Morocco, and the significant number of produced vehicle ranges. These latter have to respect perfectly the specifications and standards laid down by the parent plants and CKD (Complete Knock Down) manufacturers, to answer the original manufacturer's strategies. The mean objective of this article is to propose an Automotive Supply Chain (ASC) requirements model through the Build-To-Older (BTO) vision and Systems Engineering concept. This modeling allows us to list the mean functional requirements of the BTO system and reduce the complexity problem of the automotive supply chain. Firstly, we present the related works to BTO automotive supply chain, the Systems Engineering concept, and the requirements definition and typology. Afterward, we propose our methodological approach of requirements modeling according to SCOR Model and the SysML Language. In this approach, we integrate the different requirements, structural, and functional elements to answer correctly the parent plant expectations, which are the global performance of its supply chain. At last, we illustrate an application of the proposed model for the Moroccan ASC.

Keywords: Modeling, Requirements, Build-To-Order, SCOR model, Systems Engineering, SysML Language, Automotive Industry, Supply Chain, Morocco.

1. INTRODUCTION

The automotive industry is facing enormous and complex challenges as a result of the high prices for oil and steel, financial crisis, intensified emission controls, and trend towards electric vehicles [1]. Consequently, the parent plant requires suppliers and assembly plants to respect some specifications to answer correctly to the customer needs and the managers' strategies [2].

The successful BTO strategy starts with customer needs, which change rapidly due to his irregular and uncertain expectations. Therefore, the life cycles of customized vehicles become more shortened. For this reason, many requirements are implemented to make an ASC more performing and flexible. The mass-production method is flawed and becoming dysfunctional because of global overcapacity, rising stock levels, and low profitability. The mean goal of the BTO strategy is to build products only after the customer orders them and makes his needs visible to all parts of the value chain [3]. In the BTO approach, the challenge is the transformation of the automotive industry from mass manufacturers to BTO manufacturers [4].

In this article, we model the different BTO requirements of the automotive supply chain to attenuate and control its complexity. We also integrate into a single model, various structural and functional elements that compound our studied supply chain.

We organize the rest of the paper as follows: the second section introduces the background researches of the BTO approach in the ASC, requirements typology, and SCOR model as well as the Engineering Systems concept and SysML Language. The third section presented our studied problem and proposed approach. We show an application of the methodology in the fourth section when the last section is devoted to our conclusions to provide a new perspective.

2. BACKGROUND RESEARCHES

2.1. BTO supply chain in the automotive industry

Build-To-Order (BTO) refers to "demand-driven production where manufacturers scheduled and built-in the product to confirm received orders from final customers. These customers can be OEMs, national sales companies, car dealers, fleet orders, or other intermediaries in the supply chain"[4]. Consequently, the BTO system means a shift from a production push model to a demand-pull model. This mode is also known as integrated customer ordering, pull manufacturing, or Order-to-Delivery (OTD).

DELL firstly got a massive success in the BTO computer technology company. Since 1990, big carmakers in the world adopted the BTO approach. In 2001, a conducted study showed that the global automotive industry lost annually approximately 80 billion dollars, because of forecasted demands but never materialized [5].

In Europe, Researchers launched many theoretical studies on the BTO approach of the automobile industry. These studies include ICDP (International Car Distribution Programme) predicts that the 3-Day Car will be possible if we reduced the lead time of the painting production line. Launched in the United Kingdom in 1999, the 3-day car program consists of developing an organizational framework and process within which customer needs, for a vehicle, can be fulfilled in three days from ordering to delivery [6].

In the same context, the MVP (Minimum Viable Product) consists of introducing a version of new products in the market with essential characteristics and the least effort, but enough to get the maximum attention of the customers. Manufacturers delivered the final product in the market only after getting positive feedback from the initial users [7]. Starting with MVP in the electric vehicle network, a very well known American car marker produces a top-selling luxury car. In 2013, it was the first seller of full-size luxury Sedan in the United States [8].

Contrarily to BTO, the BTS (Build-To-Stock) approach refers to products built before identifying the final customer. It is an economic model where historical demand information and sales forecast drive the production. This approach is much more suitable for high volumes and seasonal or easy to predict demands [3].

Different researches and studies carried out in the BTO automotive supply chain. Chilin and Li (2012) integrated suppliers, distributors, and customers communities into the supply chain, to establish a collaboration model of the BTO supply chain in the automotive industry. The mean idea of this model is to recommend win-win collaboration and form communities of different levels in the whole supply chain network or further efficient utilization and optimized allocation [9]. In the ASC, the BTO strategy succeeds with three dimensions of flexibility: process, product, and production volume. The key to BTO success in auto-industry is to have standard modules configured easily per customer order. Modular assembly moves large parts of the supply chain management and component integration responsibility of first-tier suppliers, which have to deliver a complete module to the automaker [5]. The carmaker gained significant advantages of BTO: more excellent responsiveness to demand changes, lower stock volume, and no more discounting [3, 4].

Nevertheless, the BTO approach needs proactive management, given sensitivity to short-term demand fluctuations. The critical problems of the BTO system in the automotive supply chain are [9]:

- Long logistics cycle compared with short production cycle, including processing, planning, production scheduling, transportation delay, and other steps without product value;

-Lack of flexibility of manufacturing system due to lack of automatic order arrangement of components and system;

-Weaker R&D (Research and Development) ability of manufacturers and suppliers to customize new product and make rapid design changes to answer customer demands quickly;

- Out-dated IT (Information Technology) system at some suppliers, which makes the rhythm of supply chain processes and flows asynchronous and even leads to delay.

Comparing between BTO and traditional supply chain, Chilin and Li (2012**)** extracted the characteristics of a pull or BTO automotive supply chain [9], which are: flexibility of production, collaboration of suppliers, reliability and real-time of supply chain, customization of product, lowering of inventories, strategic alliance and e-business, and the pull market driven by customer orders (see Figure 1).

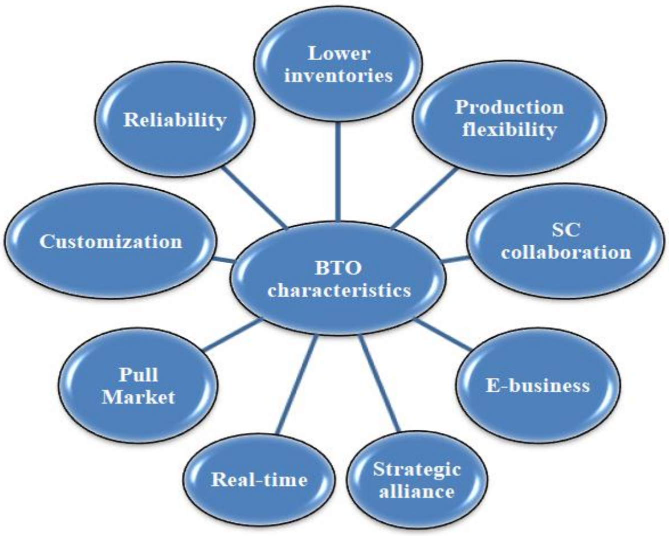


Figure 1: Characteristics of BTO Automotive Supply Chain [7].

On the other hand, we find the Engineer-To-Order (ETO) supply chains. The location of the decoupling point is at the design stage with the modification of existing designs or development of new ones, with several types of existing organizations, and customized production. Many strategies have been proposed to improve performance in the ETO supply chain, such as restructuration, flexibility, supplier integration, business systems engineering, time compression, new product development process improvement, and information management [10].

From this review, we conclude that the BTO approach aims at responding to the mean strategies and requirements of any automotive supply chain, which are a flexible, customized, real-time, reliable, collaborative, and pull supply chain.

2.2. Requirements: Definition and Typology

Requirement expresses either constraint or capacity to be satisfied by a system or a function that the system will have to carry out or a condition of technical or physical performance [11]. The definition of requirements is a description of the existing environment, which captures both the consistencies and anomalies. For this description, we use some tools such as the performed functions, the data flow, the relations between pieces of information, the significant events, and the system's performance in time [12].

Aurum et al. (2005) classified the requirements by its functionalities, levels, or by other classifications (see Table 1). There are two types of requirements: the functional and the non-functional. They depend on what the system wants to do and the constraints on the kinds of solutions to make the system more accurate, performing, secured, and modifiable. We also find two levels of requirements: primary and derived ones related to the stakeholders of the system. The requirements also rely on the business goals, the area of problem, the product specifications, and the design to build. The business needs can face the technical requirements, and the product specifications can also be versus the process exigencies. The authors also set the ones of customers, users, security, system, and Information Technologies (IT) [13].

The functional requirements represent the functions and the services of the studied system, while the non-functional requirements can be operational, environmental, or economic [14].

Table1: Classification of Requirements according to [Aurum et al., 2005]

Classification by	Type of requirement
Functionality	Functional requirements
	Non-functional requirements
Level	Primary requirements
	Derived requirements
	Goal level requirements
	Domain level requirements
	Product level requirements
	Design level requirements
Others classifications	Business requirements
	Technical requirements
	Product requirements
	Process requirements
	Role-based requirements

There are three ideal states of requirement in any development of the system [13]:

- The agreement between customer and supplier;
- The satisfaction by the sub-requirements and sub-systems or components in the lower level;
- The agreed qualification strategy.

For our studied supply chain, we will model the BTO requirements as the mean requirements to answer the customer specifications and decision-maker expectations.

2.3. SCOR Model

In 1996, the Supply Chain Council (SCC) developed the Supply Chain Operations Reference (SCOR) model. This model represents a global supply chain language that links performance metrics, processes, best practices, and people into a unified structure. This model supports communication between supply chain partners: suppliers, organizations, and customers [15]. It offers various business processes characterizing the supply chain in general: plan, source, make, deliver, and return. Figure 2 indicates these business processes in each supply chain partner.

Figure 2: SCOR Processes [SCC, 2017]

SCOR model contains three levels of process detail:

- Level 1: Five processes describe the scope and high-level configuration of a supply chain.
- Level 2: 26 processes differentiate the strategies of the first level processes.
- Level 3: 185 processes describe the steps performed to execute the second level processes.

In the SCOR model, the plan processes describe the planning operating activities in a supply chain. This process includes gathering customer requirements, collecting information on available resources, and balancing requirements and resources to determine planned capabilities and resources gaps. The source processes describe the ordering or scheduling and receipt of goods and services. It includes issuing purchase orders, scheduling deliveries, receiving shipment validation, storage, and accepting supplier invoices.

Two main business activities pilot the sourcing process: selection of new suppliers and their management over a while [16]. This selection is according to purchasing product types, either a new product, modified, urgent, or strategic purchasing [17].

According to the SCOR model, we have two mean types of BTO processes: the Make-to-Order (MTO) processes and the Engineer-to-Order (ETO) processes. The customer orders drive the MTO processes, with configurable materials and long turn-around times. Whereas, the customer requirements drive the ETO processes with new materials, extended long lead-times, and low fill rates.

Therefore, the SCOR processes describe the measures and evaluate the configuration and performance of the supply chain. These processes represent later the functional requirements of our studied supply chain.

2.4. Systems Engineering concept and SysML Language

Systems Engineering is a transdisciplinary concept to enable the successful realization, use, and retirement of engineered complex systems. It bases on systems, principles and concepts, and scientific, technological, and management methods. This notion is entirely simply transforming needs to solutions [18].

The norm ISO/IEC/IEEE 15288 defines the processes for describing the life cycle of systems and software from an engineering viewpoint. This norm applied these processes for managing and performing the life cycle of the system. These standards focus on the technical processes from the analysis of requirements to verification of the physical system architecture, by covering the design, realization, acquisition, and transfer for product utilization [19].

The concept of Systems Engineering is the most suitable to study and attenuate the complexity of our automotive supply chain. This complexity is principally due to the assembling process with more than 20,000 parts for each manufactured car [20]. It depends on the variety of product specifications, multiplicity of stocking locations, and stock aging. It also grows more with customer behavior and demand seasonality [21].

Systems Engineering is the basic concept of SysML: Systems Modeling Language [22]. This language models the requirements, the structure, and the behavior of a complex system through nine different diagrams conforming to the MBSE Approach (Model-Based Systems Engineering) (see Figure 3). This approach is a formalized application of modeling to support system requirements, design, analysis, verification, and validation, from the conceptual design to life cycle phases [23].

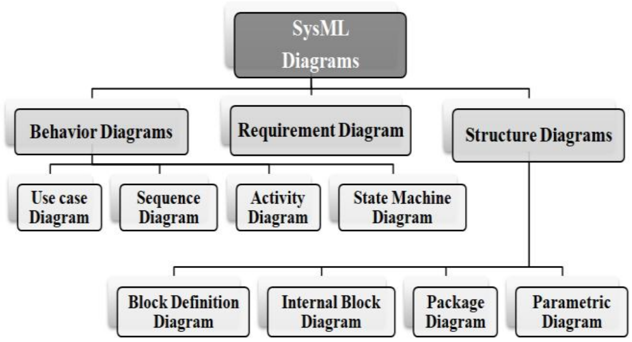
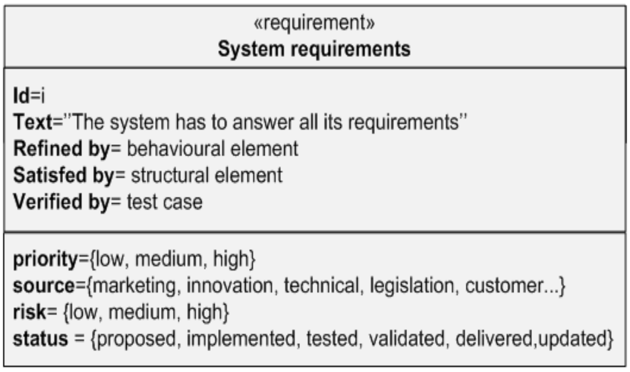


Figure 3: Diagrams of SysML Langage [OMG, 1996]

On the level of the SysML language, the requirement diagram can illustrate any requirement [11, 19, and 24]. Each one has a unique identifier, a descriptive text, a kind, a source, a validation status, relations, and degrees of priority and risk (see Figure 4).



«requirement»
System requirements

Id=i
Text="The system has to answer all its requirements"
Refined by= behavioural element
Satisfed by= structural element
Verified by= test case

priority={low, medium, high}
source={marketing, innovation, technical, legislation, customer...}
risk= {low, medium, high}
status = {proposed, implemented, tested, validated, delivered,updated}

Figure 4: Requirement Characteristics according to SysML Language

The purpose of this diagram is to conceive requirements while considering changes and future events. This diagram ensures the traceability of requirements to the structural and functional architecture of the system. It represents the graphical hierarchies of the requirements to be satisfied and responds in a particular context to any specification. It also allows linking the requirements to the structural or behavioral elements to the test cases, as well as to the other requirements of the sub-systems, through relations of containment, derivation, refinement, satisfaction, traceability, and verification. Systems Engineering helps to create better requirements [11].

In the literature, most researches do not take into consideration the BTO requirements during the conception and modeling of a complex ASC. Hence, we need to adopt the Systems Engineering to redefine our chain with a new concept and visibility of different mean elements. We present below our defined problem and methodology.

3. PROBLEM FORMULATION AND RESEARCH METHODOLOGY

We define our problem as follows (1): a given requirement R_i (2) may be satisfied by a set of sub-systems or components S (3) when a given supply sub-system or component S_j has to satisfy a set of requirements R [25].

$$S \vDash R \tag{1}$$

$$R = \sum_{i=1}^{m} R_i \tag{2}$$

$$S = \sum_{j=1}^{n} S_j \tag{3}$$

Every sub-system or component S_j has to realize one or more functions (4), while each function or activity F_k has to allocate one or more sub-systems or components (5).

$$F = \sum_{k=1}^{p} F_k \tag{4}$$

$$F \rightarrow S \tag{5}$$

In Figure 5, we illustrated different possible relations of satisfaction and allocation between requirements, systems, and functions.

SysML language includes allocation relations to represent different physical and logical allocations, such as from functions to components, from logical elements to physical components, as well as from software to hardware. The significant contribution of SysML with the allocation mechanism is to make visible and exploitable interconnections.

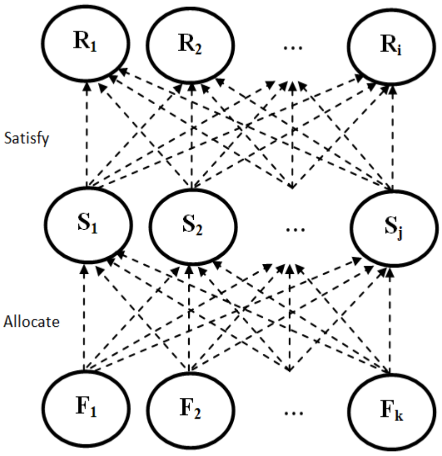


Figure 5: Satisfaction and Allocation Relations between Requirements, Systems, and Functions

In Figure 6, we propose a meta-model to show the different relations between system requirements and the other structural and functional elements. We integrate different parameters of different natures. This meta-model illustrates:

- The satisfaction relation between the system requirement with the various structural elements such as blocks.
- The verification relation with parametric constraints and test cases;
- The refinement relation with functional use cases;
- The realization and allocation relations between components and use cases;
- The generalization relation between a use case and activity;
- The composite association between the studied system and its sub-systems and components.

In this meta-model, we integrate into a single model, several heterogeneous elements such as system, functions, requirements, and constraints. Each component of the system can be either an actor or a resource.

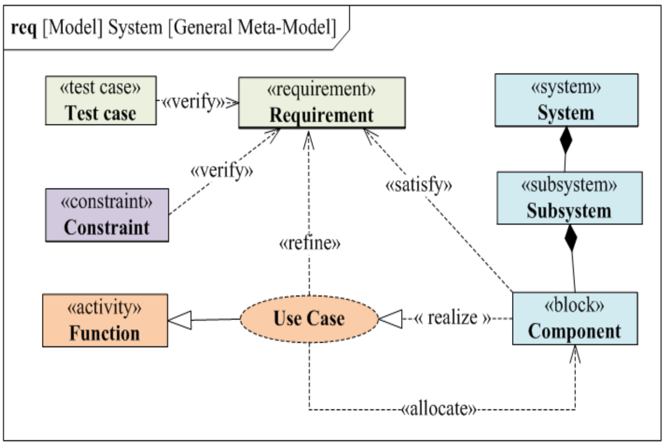


Figure 6: Meta-Model of a Requirement with Different Structural and Behavioral Elements

We used the SysML requirements diagram to model our BTO specifications and describe each requirement, its sub-requirements, its different derivations, and compositions between functional and structural elements. We also proposed a general diagram of the functional and non-functional BTO requirements of our system in Figure 7. Every input requirement has derived requirements with derivation and containment associations.

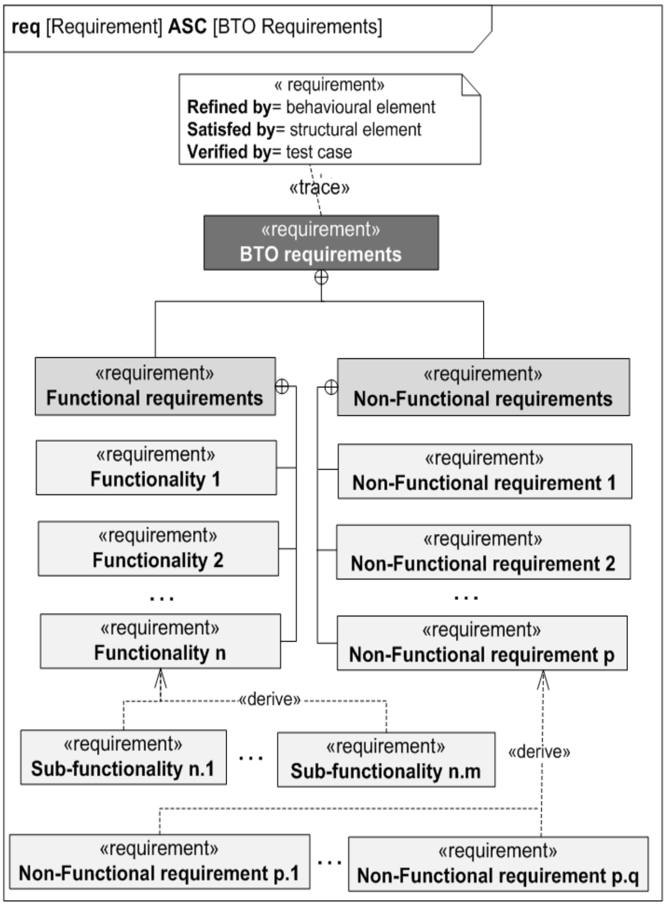


Figure 7: General BTO requirements Diagram

We define these requirements as follows:

- The system has to answer all its functional and non-functional BTO requirements;
- The system has to answer all its functional BTO requirements;
- The system has to ensure its sub-functionalities;
- The system has to answer all its non-functional BTO requirements.

We adopted the Systems Engineering approach and SysML language, to reduce the complexity of an ASC and improve its performance. This approach permits us to model our supply chain as a system and its subsystems, with different types of relations, components, and functions. These latter should principally answer the functional and non-functional BTO requirements.

We chose the Source process as the most complicated process in the automotive supply chain, according to the literature. The mean Sourcing processes, according to the SCOR model and the BTO specificities, are Plan Source, Source Make-to-Order, and Source Engineer-to-Order. We illustrate the three levels of these sourcing processes in Tables 2, 3, and 4.

Table 2: Plan Source Processes according to SCOR 12.0

Levels	Processes
Level 1	Plan
Level 2	Plan source
Level 3	Identify, prioritize, and aggregate product requirements
	Identify, assess, and aggregate product resources
	Balance product resources with product requirements
	Establish sourcing plans

Table 3: Source Make-to-Order Processes according to SCOR 12.0

Levels	Processes
Level 1	Source
Level 2	Source Make-to-Order
	Schedule product deliveries
	Receive product
	Verify product
	Transfer product
	Authorize supplier payment

Table 4: Source Engineer-to-Order Processes according to SCOR 12.0

Levels	Processes
Level 1	Source
Level 2	Source Engineer-to-Order
Level 3	Identify sources of supply
	Select the final supplier(s) and negotiate
	Schedule product deliveries
	Receive product
	Verify product
	Transfer product
	Authorize supplier payment

Our Methodological approach consists of developing a requirements model based on BTO requirements, SCOR sourcing processes, and SysML Requirements diagram. This approach combines the process approach and engineering systems approach, to give a new definition of our complex supply chain and reduce its complexity. The requirements engineering and management ensure their coherence and traceability [26].

In this paper, we propose the different functional and non-functional requirements of the BTO ASC. We also illustrate various stakeholders and requirements set by the whole sourcing system to show and reduce the problem of structural and behavioral complexity of this chain.

The main contribution of this work is to provide a BTO requirements design model, as a preliminary decision support tool for the ASC, by combining business processes model and systems engineering concept. Through this model, we want to answer the mean BTO characteristics of the ASC, which are flexibility, just in time, pull production, suppliers collaboration, and customized products.

The next section is an application of the proposed model in the Moroccan automotive supply chain. The used tool for modeling is Microsoft Visio SysML Template 2007.

4. APPLICATION TO THE MOROCCAN AUTOMOTIVE SUPPLY CHAIN

4.1. Presentation of Moroccan automotive industry

As a mighty pillar in the national economy, the Moroccan automotive industry actively contributes to improve the industrial GDP (Gross Domestic Product). It ensures a large volume of imports and exports and positively influences on job growth, development, and extension of industrial infrastructure. The Moroccan automotive sector is positioned as the leading export sector in Morocco ahead of phosphates and agriculture sectors, and the second one in Africa after South Africa [27-29].

The National industrial acceleration strategy 2014-2020 come to give a new impulsion to this sector, to create an automotive fabric with a more integrated value chain in the context of global mutations. Among the targeted projects, we find industrial investment fund of 20 billion dirhams, development of its local integration rate from 45 to 65% by 2020, creation of 90,000 additional jobs, and production capacity of 400,000 vehicles per year [29].

This Moroccan industry based on two main activities, namely: the assembly of CKD parts by automotive parent plants and the manufacturing of automotive components by National or International OEM [30]. The next figure (Figure 8) represents the general structure of the automotive supply chain in Morocco.

Between 1995 and 2014, Morocco moved from weak to neutral country according to the Economic Complexity Index (ECI). This index ranked Morocco in the 78th spot out of 124 countries and evaluated the degree of cognitive and productive abilities from its exports and product diversification [31].

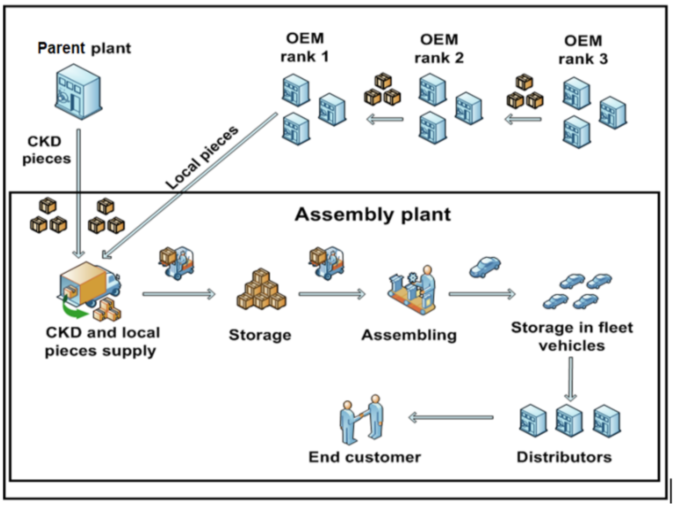


Figure 8: The General Structure of the MASC

Besides, some specificities of the MASC increase more its complexity. We find a variety of cultures due to the foreign installed providers and suppliers either from the United States, Japan, Germany, France, Spain, or others [30]. We also notice the non-conformity of Electronic Data Interchange (EDI) in some SME suppliers [32]. We find that the logistic maturity of this type of OEM is limited to fragmented and unformalized logistics, which prevents their collaboration and integration into the supply chain [33]. As well, we perceive the problem of synchronization of raw material flows between the automaker and the OEM [34]. Also, we notice the lack of expertise in design and R&D in the Moroccan automotive SMEs to move up more to technology-based manufacturing and away from low-cost manufacturing hub. Consequently, the government aims at increasing export diversification to other developing countries and emerging markets and improving local integration of suppliers form 40% to 70% [35].

Through this literature, we listed the different requirements concerning the Moroccan Automotive Supply Chain (MASC):

-Time: Make just in time and deliver the vehicle on the promised date already announced to the customer;

-Cost: Reduce logistics costs from supplier to final delivery;

-Quality: Ensure both the quality of the physical flows (product) and information flows (documentation);

-Standardization: Work is identical across an extensive network of factories and suppliers around the world;

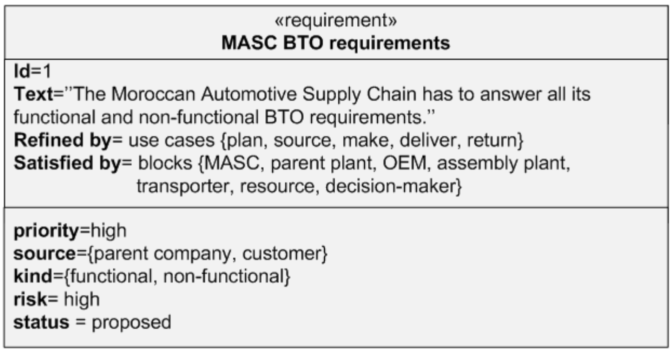
-Flexibility: Adapt the flexibility of the entire logistic system with the time requirement;

-BTO: Produce with pull flows according to the customer order, to give the best visibility to all the partners of the supply chain.

To attenuate the automotive sourcing complexity, we adopt the BTO approach required by the automotive supply chain and the engineering concept dedicated to complex systems. In the next part, we propose our BTO requirements model of the Moroccan complex ASC.

4.2 Proposition of BTO Requirements Model of Moroccan Automotive Supply Chain via SysML Language and SCOR Model

The Moroccan Automotive Supply chain (MASC) aims to build cars according to customer orders defined before by the marketing department. So it should respond to customer requirements according to the BTO approach. Before illustrating our BTO requirements Model, we generally describe the characteristics of the MASC in Figure 9. Therefore, our supply chain has to answer all its functional and non-functional BTO requirements. These requirements have a high priority due to the considered risks that the supply chain may encounter in the case of customer order failure.



«requirement»
MASC BTO requirements

Id=1
Text=”The Moroccan Automotive Supply Chain has to answer all its functional and non-functional BTO requirements.”
Refined by= use cases {plan, source, make, deliver, return}
Satisfied by= blocks {MASC, parent plant, OEM, assembly plant, transporter, resource, decision-maker}

priority=high
source={parent company, customer}
kind={functional, non-functional}
risk= high
status = proposed

Figure 9: BTO Requirements Characteristics of the MASC

In the case of the Moroccan Automotive Sourcing Chain, the BTO requirements are refined by the sourcing processes and satisfied by the decision-makers. These latter can be either in the level of the parent plant, the OEM, or the assembly plant, which are the mean actors of the sourcing MASC. The decision-maker can also be either a manager, a coordinator, a configurator, or an information system. He has to plan and order the MTO or ETO products either for regular components or new ones (see Figure 10).

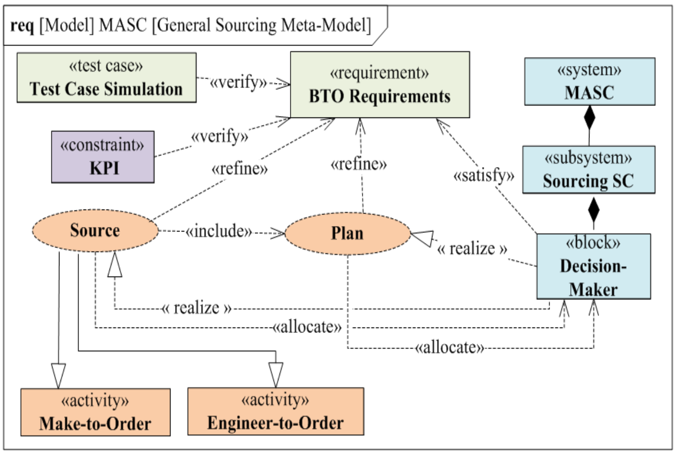


Figure 10: Meta-Model of BTO Requirements of the Moroccan Sourcing ASC.

In our previous work [36], we illustrated the actors and the functionalities of the MASC using the block definition and use case SysML diagrams. In the next research paper, we will develop the test case simulation and the Key Performance Indicators (KPI) to verify the BTO requirements.

Conforming to the literature review of BTO ASC in general and MASC in particular, we extracted the mean non-functional BTO requirements in Figure 11. The mean non-functional requirements are flexibility, just-in-time, collaboration, and customization.

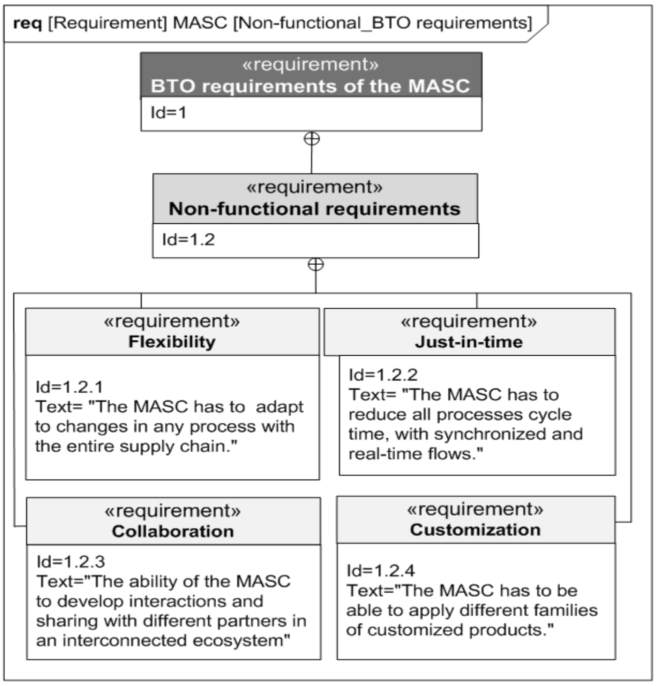


Figure 11: Non-Functional Requirements Model of the BTO Moroccan Automotive Supply Chain

Before modeling the functional BTO sourcing requirements, we illustrate the general functional requirements of the MASC, based on the SCOR Model and SysML requirements diagram (see Figure 12). The MASC has to answer all its functional requirements from planning to return processes. We detail the description of these requirements in Table 5.

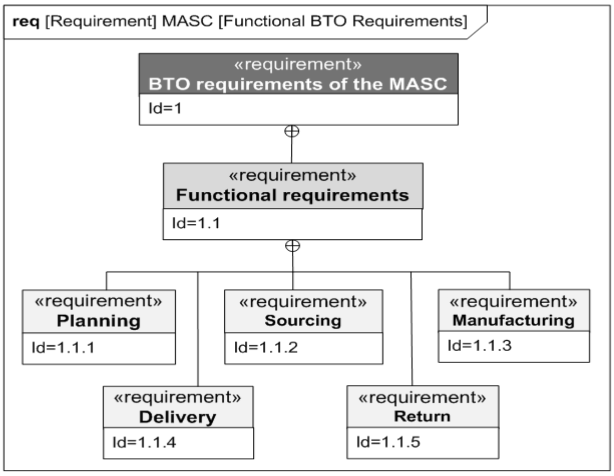


Figure 12: Functional Requirements Model of the BTO Moroccan Automotive Supply Chain

Table 5: Functional Requirements of the BTO MASC

Req Id	Requirement Name	Requirement Description
1.1	Functional requirements	"The MASC has to answer all its functionalities."
1.1.1	Planning	"The MASC has to plan its resources and capabilities. "
1.1.2	Sourcing	"The MASC has to ensure the ordering, scheduling, and receipt of components."
1.1.3	Manufacturing	"The MASC has to ensure the conversion of the components."
1.1.4	Delivery	"The ASC has to ensure the creation, maintenance, and fulfillment of orders."
1.1.5	Return	"The MASC has to manage the reverse flow of products back from the assembly plant (non-conforming products, durable packaging, and others)."

The MASC has to plan the sourcing of its BTO components before every order. The decision-maker should identify, prioritize, and aggregate the product requirements and identify, assess, and aggregate the product resources. After, it has to balance resources capabilities with customer requirements. Then, the sourcing manager establishes and communicates the sourcing plans to supply service to start ordering (see Figure 13 and Table 6).

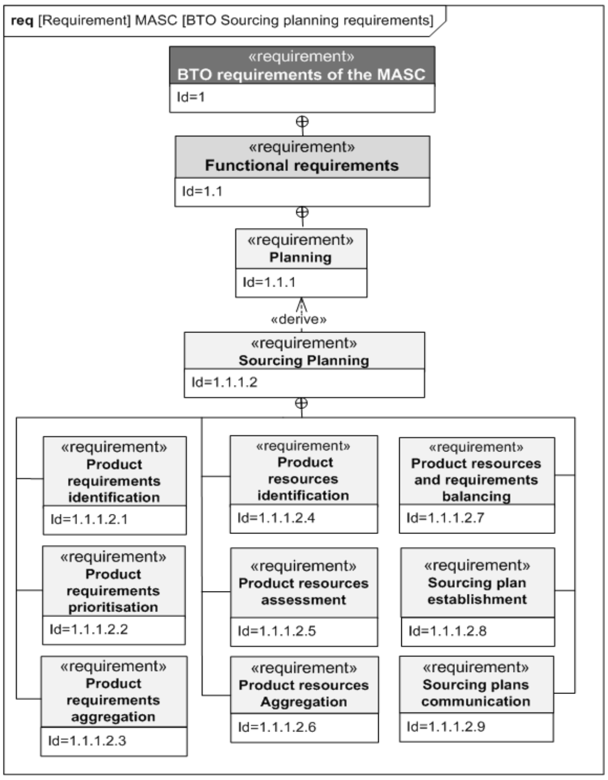


Figure 13: BTO Sourcing Planning Requirements Model of the MASC

Table 6: BTO Sourcing Planning Requirements of the MASC

Req Id	Requirement Name	Requirement Description
1.1.1	Planning	"The MASC has to plan its resources and capabilities. "
1.1.1.2	Sourcing Planning	"The MASC has to determine the planned capabilities and resources gaps to balance the product resources with customer requirements."
1.1.1.2.1	Product requirements identification	"The MASC has to identify customer requirements."
1.1.1.2.2	Product requirements prioritization	"The MASC has to prioritize customer requirements."
1.1.1.2.3	Product requirements aggregation	"The MASC has to aggregate the customer requirements."
1.1.1.2.4	Product resources identification	"The MASC has to identify the capabilities of product resources."
1.1.1.2.5	Product resources assessment	"The MASC has to assess the capabilities of product resources."
1.1.1.2.6	Product resources aggregation	"The MASC has to aggregate product resources."
1.1.1.2.7	Product resources and requirements balancing	"The MASC has to balance the resources capabilities with customer requirements."
1.1.1.2.8	Sourcing plan establishment	"The MASC has to establish sourcing plans."
1.1.1.2.9	Sourcing plans communication	"The MASC has to communicate the sourcing plans to supply service."

As we defined before, the MASC has to order the car components according to the MTO or ETO approach. For new parts, the sourcing or purchasing manager has to identify the supply sources, negotiate with suppliers, and select the good ones (see Figure 14 and Table 7). For both approaches, the supply manager has to schedule product deliveries, then receipt, verify, and transfer the right component, and finally authorize the supplier payment in the information system (see Figure 14, 15, and Table 7, 8).

Based on the requirements diagrams previously developed, we show the sequence of actions and decisions within BTO sourcing requirements. In the case of ETO components, if the product requirements and resources are balanced, the sourcing plans are established and communicated to the supply service. If they are unbalanced, the decision-maker re-identifies the resources and its capabilities. After receipt, the right ETO or MTO components are verified and transferred to warehouses. In the case of minor non-conformity, the terminal assembly factory returns the wrong component to the supplier waiting for its exchange. In the significant non-conformity, an audit will be launched to decide on the supplier situation. The decision can be a warning, penalty, contract cancellation, or a new supplier selection. Our activity diagram represents later an algorithm to simulate (see Figure 16).

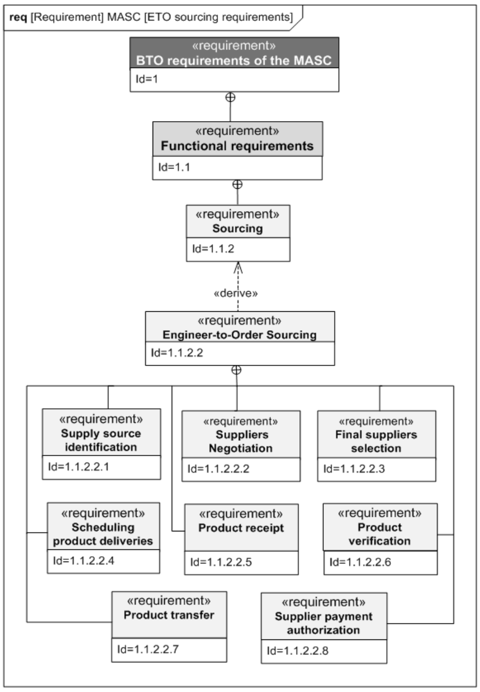


Figure 14: ETO Sourcing Requirements Model of the MASC

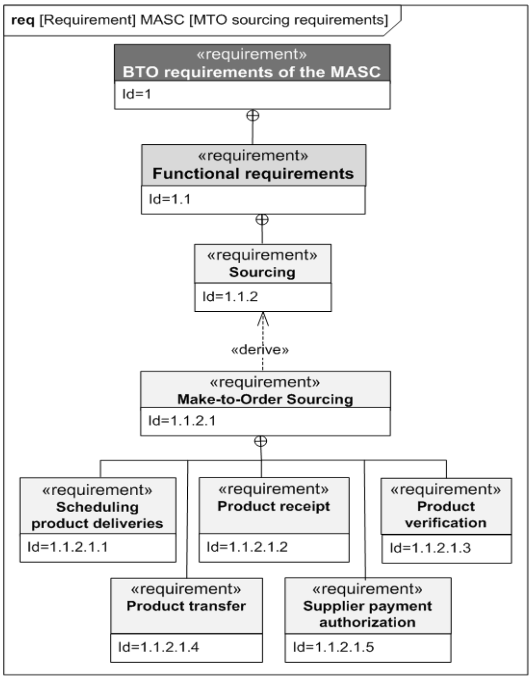


Figure 15: MTO Sourcing Requirements Model of the MASC

Table 7: ETO Sourcing Requirements of the MASC

Req Id	**Requirement Name**	**Requirement Description**
1.1.2	Sourcing	"The MASC has to ensure the ordering, scheduling, and receipt of components."
1.1.2.2	Engineer-to-Order Sourcing	"The MASC has to order ETO components."
1.1.2.2.1	Supply source identification	"The MASC has to identify the sources of ETO components."
1.1.2.2.2	Suppliers Negotiation	"The MASC has to negotiate with suppliers, different criteria of the ETO components."
1.1.2.2.3	Final suppliers selection	"The MASC has to select the final supplier or suppliers of the ETO components."
1.1.2.2.4	Scheduling product deliveries	"The MASC has to schedule the ETO deliveries from different OEMs."
1.1.2.2.5	Product Receipt	"The MASC has to ensure the receipt and unloading of delivered ETO products."
1.1.2.2.6	Product verification	"The MASC has to ensure the quantitative and qualitative control of its received ETO products."
1.1.2.2.7	Product transfer	"The MASC has to ensure the ETO product transfer and handling, from the receipt to the warehouse."
1.1.2.2.8	Supplier payment authorization	"The MASC has to ensure the payment of the supplier, once the receipt is accepted."

Table 8: MTO Sourcing Requirements of the MASC

Req Id	**Requirement Name**	**Requirement Description**
1.1.2	Sourcing	"The MASC has to ensure the ordering, scheduling, and receipt of components."
1.1.2.1	Make-to-Order Sourcing	"The MASC has to order MTO components."
1.1.2.1.1	Scheduling product deliveries	"The MASC has to schedule the MTO deliveries from different OEMs."
1.1.2.1.2	Product receipt	"The MASC has to ensure the receipt and unloading of delivered MTO products."
1.1.2.1.3	Product verification	"The MASC has to ensure the quantitative and qualitative control of its received MTO products."
1.1.2.1.4	Product transfer	"The MASC has to ensure the MTO product transfer and handling, from the receipt to the warehouse."
1.1.2.1.5	Supplier payment authorization	"The MASC has to ensure the payment of the supplier, once the receipt is accepted."

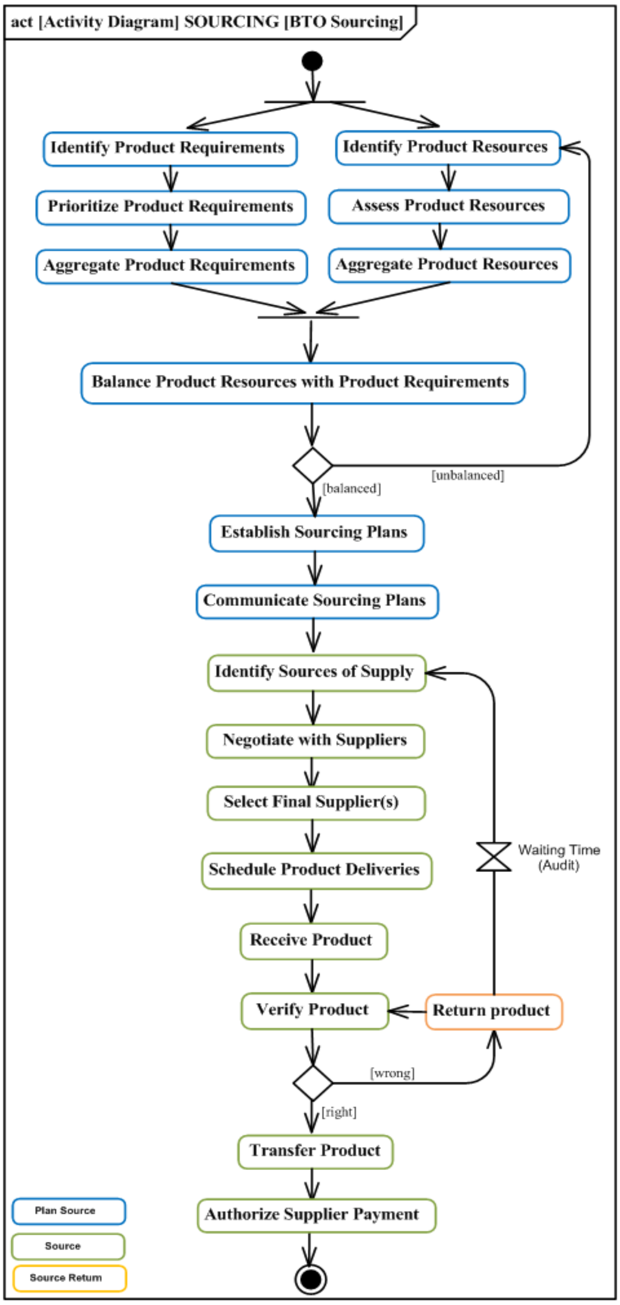


Figure 16: Activity Diagram of the Plan-Source Requirements for ETO MASC

Through the concept of system engineering, we tried to answer to the problem of structural and behavioral modeling of a complex automotive supply system, by integrating the BTO requirements. This modeling will mitigate the complexity of the automotive supply chain and will effectively contribute to the improvement, optimization, and simulation of its performance as a decision support tool.

Through the modeling of the requirements of our supply chain, we have shown their relations with the different structural and behavioral elements. In the proposed model, we listed the requirements of the system, especially those of functionality and BTO specifications, linked to all architectural and functional items, integrating the notion of requirement from the conception. The importance of our model is to respond to customer requirements by the BTO specifications, which aim to have a flexible, real-time, collaborative, and customized supply chain.

5. CONCLUSION AND FUTURE PROSPECTS

The proposed model in this article allowed us to illustrate the Moroccan Automotive Supply Chain (MASC) by modeling the functional and non-functional requirements. For this model, we relied on the BTO approach, the SCOR Model, and the SysML diagrams. This model gives a better redefinition of the supply chain from the conception, by integrating the different structural and behavioral elements and showing the diverse relations between the requirements and the automotive supply chain. In the prospects, we will study the BTO requirements with considered risks and constraints influencing the whole performance of our system.

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APPENDIX: ACRONYMS LIST

ASC	Automotive Supply Chain
BTO	Build-To-Order
BTS	Build-To-Stock
CKD	Complete Knock Down
ECI	Economic Complexity Index
EDI	Electronic Data Interchange
ETO	Engineer-to-Order
GDP	Gross Domestic Product
KPI	Key Performance Indicators
ICDP	International Car Distribution Programme
Id	Identifier
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
MASC	Moroccan Automotive Supply Chain
MBSE	Model-Based Systems Engineering
MTO	Make-to-Order
MVP	Minimum Viable Product
OEM	Original Equipment Manufacturer
OTD	Order-to-Delivery
R&D	Research and Development
Req	Requirement
SC	Supply Chain
SCC	Supply Chain Council
SCOR	Supply Chain Operation Reference
SME	Small and Medium Enterprises
SysML	Systems Modeling Language

REFERENCES

[1] Ericsson, R., Becker, R., Döring, A., Eckstein , H., Kopp, T., Poslu, I., and Váncza, J., 2010, "From Build-to-Order to Customize-to-Order, Advancing the Automotive Industry by Collaboration and Modularity," Code of Practice Findings of the EU-FP6 Project AC/DC, Automotive Chassis Development for 5-Days Cars.

[2] Ibn El Farouk, I., 2015, "Pilotage of Logistic Performance of the Automotive OEM, case of Renault," Plenary Conference No. 4, the 8th International Conference on Logistics and Supply Chain Management (Logistiqua), Morocco, (in French).

[3] Holweg, M., and Pil, F. K., 2001, "Successful Build-to-Order Strategies Start with the Customer," MIT Sloan Management Review, pp.74-83, Vol.43, No.1.

[4] Parry, G., and Graves, A., 2008, "Build To Order, the road to the 5-Day Car," School of Management, University of Bath, Springer.

[5] Polly, L., 2002, "Industry and Trade Summary of Motor Vehicles," Office of Industries, US International Trade Commission, Washington, USITC Publication 3545.

[6] Holweg, M., and Miemczyk, J., 2003, "Delivering the 3-Day Car, the Strategic Implications for Automotive Logistics Operations," Journal of Purchasing and Supply Management, 9(2), pp. 63–71.

[7] Ries, E., 2011, "The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses, " Kindle Edition.

[8] Stringham, E. P., Miller, J. K., and Clark, J. R., 2015, "Overcoming Barriers to Entry in an Established Industry: Tesla Motors," California Management Review, 57(4), pp. 85–103.

[9] Chilin, L., and Li, Y., 2012, "Research on Supply Chain Collaboration of Auto Industry Engineering Based on BTO," Systems Engineering Procedia 5, pp. 398–404.

[10] Gosling, J., and Naim, M. M., 2009, "Engineer-to-Order Supply Chain Management: a Literature Review and Research Agenda," International Journal of Production Economics 122, pp.741-754.

[11] Roques, P., 2009, "SysML by Example, a Modeling Language for Complex Systems," Eyrolles Edition. (in French).

[12] Bravoco, R.R., and Yadav, S.B., 1985, "Requirement Definition Architecture- an Overview," Computers in Industry 6, Elsevier Science Publishers B.V., North-Holland, pp. 237-251.

[13] Aurum, A., and Wohlin, C., 2005, "Engineering and Managing Software Requirements," Springer Berlin Heidelberg New York.

[14] Chalfoun, I., Kouiss, K., Bouton, N., and Ray, P., 2014, "Specification of a Reconfigurable and Agile Manufacturing Systems (RAMS)," International Journal of Mechanical Engineering and Automation, Vol. 1, No. 6, pp. 387-394.

[15] SCC, 2017, "Supply Chain Operations Reference (SCOR) model," American Production and Inventory Control Society and Supply Chain Council, Overview Version 12.0.

[16] Scott, C., Lundgren, H., and Thompson, P., 2018, "Guide to Supply Chain Management, an End to End Perspective," Management for Professionals, Second Edition, Springer.

[17] Aguezzoul, A., and Ladet, P., 2006, "Selection and Evaluation of Suppliers: Criteria and Methods," French Journal of Industrial Management, 2, pp.5-27 (in french)

[18] INCOSE, 2019, "About Systems Engineering," International Council on Systems Engineering.

[19] ISO, 2015, "ISO/IEC/IEEE 15288: Systems and Software Engineering - System Life Cycle Processes," First Edition.

[20] Dreher, D., 1997, "Logistics Benchmarking in the Automobile Industry: a Leadership Instrument for Increasing Competitiveness (Planning, Organization, and Enterprise Conduct)," Paperback January 1, (in German).

[21] Turner, K., and Williams, G., 2005, "Modeling Complexity in the Automotive Industry Supply Chain," Journal of Manufacturing Technology Management, Vol.16 Iss.4, pp. 447–458.

[22] OMG, 2017, "SysML: Systems Modeling Language," Object Management Group, Version 1.5.

[23] Friedenthal, S. A., Griego, R., and Sampson, M., 2007, "INCOSE Model-Based Systems Engineering (MBSE) Initiative," INCOSE Symposium, June 24-29th, San Diego.

[24] Fagnon, D., and Gaston, S., 2012, "SysML the Diagrams," TECHNOLOGIE N°179, pp. 100-104, (in French).

[25] Pétin, J. F., Evrot, D., Morel, G., and Lamy, P., 2010, "Combining SysML and Formal Methods for Safety Requirements Verification," 22nd International Conference on Software Systems Engineering and their Applications, Paris, France, pp. CDROM.

[26] Hull, E., Jackson, K., and Dick, J., 2005, "Requirement Engineering," Second Edition, Springer.

[27] Exchange Office, 2013, "The Automotive Industry in Morocco, Export Performance," Report, Foreign Trade Statistics Department (in French).

[28] Ministry of Industry, Investment, Trade, and Digital Economy, 2014, "Study for Private Sector Development in the Kingdom of Morocco, Information Collection and Analysis," Final Report, Japanese Agency of International Cooperation (in French).

[29] Ministry of Economy and Finance, 2015, "The Automotive Sector in Morocco: Towards a Better Position in the Global Value Chain," Report, Direction of Studies and Financial Prevision (in French).

[30] Adnan, S., 2013, "The Automotive Industry in Morocco, Opportunities, and Perspectives," Moroccan Association for Automotive Industry and Trade, Stuttgart.

[31] Hausmann, R., Hidalgo, CA., Bustos, S., Coscia, M., Chung, S., Jimenez, J., Simoes, A., and Yildirim, M., 2014, "The Atlas of Economic Complexity," Puritan Press, Cambridge.

[32] Jardini, B., El Kyal, M., and Amri, M., 2015, "the Complexity of Electronic Data Interchange (EDI) Compliance for Automotive Supply Chain," International Conference on Industrial Engineering and Engineering Management IEEM IEEE, Singapore, pp.361-365.

[33] Rahoum, K., and Jamouli, H., 2015, "Analysis and Evaluation of the Moroccan Automotive Supply Chain," Proceeding of Xth International Conference of Integrated Design and Production, Morocco, pp. CDROM, (in French).

[34] Ibn El Farouk I., and Jawab, F., 2017, "Synchronous Flow in Automotive Industry Case Study of RENAULT," International Colloquium on Logistics

and Supply Chain Management (LOGISTIQUA), IEEE, Rabat, Morocco, pp. 199-203.

[35] Hahn, T., and Auktor, G. V., 2017, "The Effectiveness of Morocco's Industrial Policy in Promoting a National Automotive Industry, " Discussion Paper, No. 27/2017, Deutsches Institut für Entwicklungspolitik, DIE, Bonn.

[36] Rahoum, K., and Jamouli, H., 2019, "Towards a Reconfigurable Automotive Supply Chain via Systems Engineering Concept," Proceeding of the 7th IEEE International Conference on Advanced Logistics and Transport – ICALT 2019, Marrakech, Morocco, pp. 151-156.