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Towards Hyperconnected Resource Requirements Planning

Raphaël OGER[1,2], Matthieu LAURAS[1], Benoit MONTREUIL[2],
Frédérick BÉNABEN[1] and Nicolas SALATGE[1]

1. Industrial Engineering Center, IMT Mines Albi-Carmaux, Toulouse University, Albi, 81000, France
2. Physical Internet Center, ISYE School, Georgia Institute of Technology, Atlanta, GA 30332-0205, U.S.A

Corresponding author: raphael.oger@mines-albi.fr

Abstract: *This paper focuses on Resource Requirements Planning (RRP) for hyperconnected supply chain. The objective is to enable Physical Internet (PI) Logistics Web actors to plan their resources effectively to be able to fulfill the demand in the forthcoming years. We first identify a lack of research literature about RRP for hyperconnected supply chains. We conclude from our literature review that the research efforts done by the PI community are focused on enabling the PI to become operational. But the PI community has not yet shown any interest in PI strategic planning. So, we position our research regarding the MRP II system's RRP, focusing on the strategic planning processes for production and capacity control. Therefore, from the lack of research literature about RRP for hyperconnected supply chains, and from the MRP II strategic planning methodology structure, we demonstrate the significant need to adapt this MRP II system's RRP to fit the hyperconnected supply chains requirements and so the PI requirements. Finally, we introduce a Physical Internet Resource Requirement Planning (PI-RRP) methodology corresponding to our research agenda guidelines. The development of this methodology will drive our futures researches.*

Keywords: *Physical Internet, Logistics Web, Realization Web, Supply Chain, Strategic Planning, Resource Requirements Planning, Decision Support System, Information Systems.*

1 Introduction

Over recent years, the Physical Internet (PI) (Montreuil et al., 2010; Montreuil, 2011) gained significant attention from the academic and practitioner communities (Treiblmaier et al., 2016). This idea of designing and managing logistics flows (material, information and money) in a way inspired from the way the digital internet deals with data flows (Montreuil et al., 2012) appeals to both communities. The PI Foundations Framework introduced by Montreuil et al. (2013) proposes some guidelines to reach the PI ambitions. Through this framework, the PI is defined as "*an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols*" (Montreuil et al., 2013).

As expressed by Montreuil (2015), the PI aims to enable efficient and sustainable hyperconnected supply chains and logistics system, their components intensely interconnected on multiple layers, ultimately anytime, anywhere.

In this paper, we focus on Resource Requirements Planning (RRP) in such hyperconnected supply chains. For supply chain actors, the aim of the historical MRP II system's RRP is to plan their resources effectively so as to be able to fulfill demand in the forthcoming years (Arnold et al., 2008; Olhager et al., 2001).

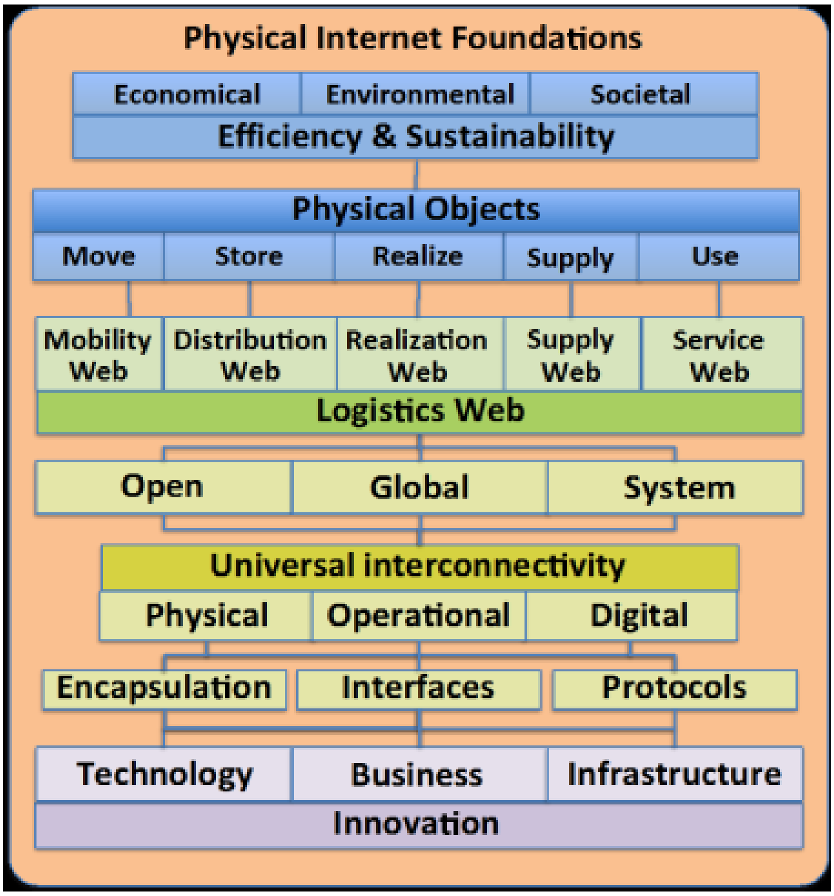

Figure 1: Physical Internet Foundation Framework (Montreuil et al., 2013)

After having further explained the lack of research literature about RRP for hyperconnected supply chains, we position our research regarding the MRP II system's RRP. Then, we demonstrate the need to adapt this MRP II system's RRP to fit the hyperconnected supply chains requirements. Finally, we introduce a Physical Internet Resource Requirement Planning (PI-RRP) methodology corresponding to our research agenda guidelines. To address this PI-RRP challenge and to design the PI-RRP methodology, we take advantage of the IO-Suite project aiming to support interoperability of collaborative networks (Benaben et al., 2014), as well as the PI foundation framework (Montreuil et al., 2013).

2 Background and research statement

2.1 Background

2.1.1 Physical Internet background regarding Resource Requirements Planning

In our journey to design a RRP for hyperconnected supply chains, we show a major interest in the literature about the PI strategic planning, considering the following elements in our literature review: strategic business planning, business planning, sales and operation planning, resource requirements planning, resource planning, strategic capacity planning, and capacity planning.

We started our literature review on these topics considering the literature review about the PI done by Treiblmaier et al. (2016). We choose to highlight three of their tables which synthetize some of their research results: "PI Components Reviewed by the Literature", "Key Performance Indicators and Goals of the PI", and "Problems and unanswered questions related to the PI". We observe that the literature focuses on PI operational challenges. From Treiblmaier et al. (2016) results, neither the "PI Components Reviewed by the Literature" nor the “Key Performance Indicators and Goals of the PI” table contains research information about the considered PI strategic planning elements mentioned previously. From the “PI Components Reviewed by the Literature” table, Treiblmaier et al. say that “prior literature has invested considerable efforts in establishing the foundations of the PI components and further improving the same by working on practical solutions”. The following PI components have been identified:

- Modular containers (transport containers, handling containers, packaging containers)
- Vehicle usage optimization
- Transit centers, hubs
- Seamless, secure and confidential data exchange
- Legal framework
- Cooperation models
- Business models

From the “Key Performance Indicators and Goals of the PI” table, Treiblmaier et al. say that “most of the literature focuses on the development of performance indicators addressing the main goals of the PI: logistics effectiveness, efficiency and sustainability”. To summarize PI KPIs considered within the literature, we classified them within two categories:

- Transportation optimization and evaluation, from economic, environmental and societal perspectives.
- PI containers and PI infrastructure durability.

Finally, Treiblmaier et al. concluded their literature review by a synthesis of the PI related problems addressed by the literature, and a list of PI related unanswered questions they identified for additional research opportunities. The PI related challenges considered in the literature and the PI related unanswered questions might be summarize as the following questions:

- How to deal with the Physical Objects (designing PI containers, PI hubs, etc.)?
- How to design and manage the Logistics Web (transportation optimization, cooperation model, etc.)?
- How to manage the interconnectivity between all the Logistics Web components (Interconnectivity protocols, security, legality, openness, etc.)?

Within this literature review done by Treiblmaier et al. (2016), we did not found any papers about PI strategic planning. Therefore, in addition of the work done by Treiblmaier et al., we searched specifically for PI strategic planning researches considering the elements previously mentioned: strategic business planning, business planning, sales and operation planning, resource requirements planning, resource planning, strategic capacity planning, and capacity planning (all combined with Physical Internet). However we did not found either papers about PI strategic planning.

To conclude our literature review, the research efforts done by the PI community are focused on enabling the PI to become operational and making it efficient and sustainable. The PI community has not yet shown any interest in PI strategic planning, and mainly stay focused on the operational challenges. There is no research about the evaluation of the Logistics Web ability to fulfil the demand.

2.1.2 Research positioning regarding the MRP II system: Business Planning, Sales and Operation Planning, and Resource Requirements Planning

As the PI community has not yet shown any interest for PI strategic planning, we decided to use the historical MRP II system. Exploiting this MRP II system is one of the current dominant approaches in practice for performing Make To Stock manufacturing planning. MRP II is a method for the effective planning of all resources of a manufacturing company, driving the company manufacturing planning process from the business plan to the operational activities (Figure 2) (Arnold et al., 2008).

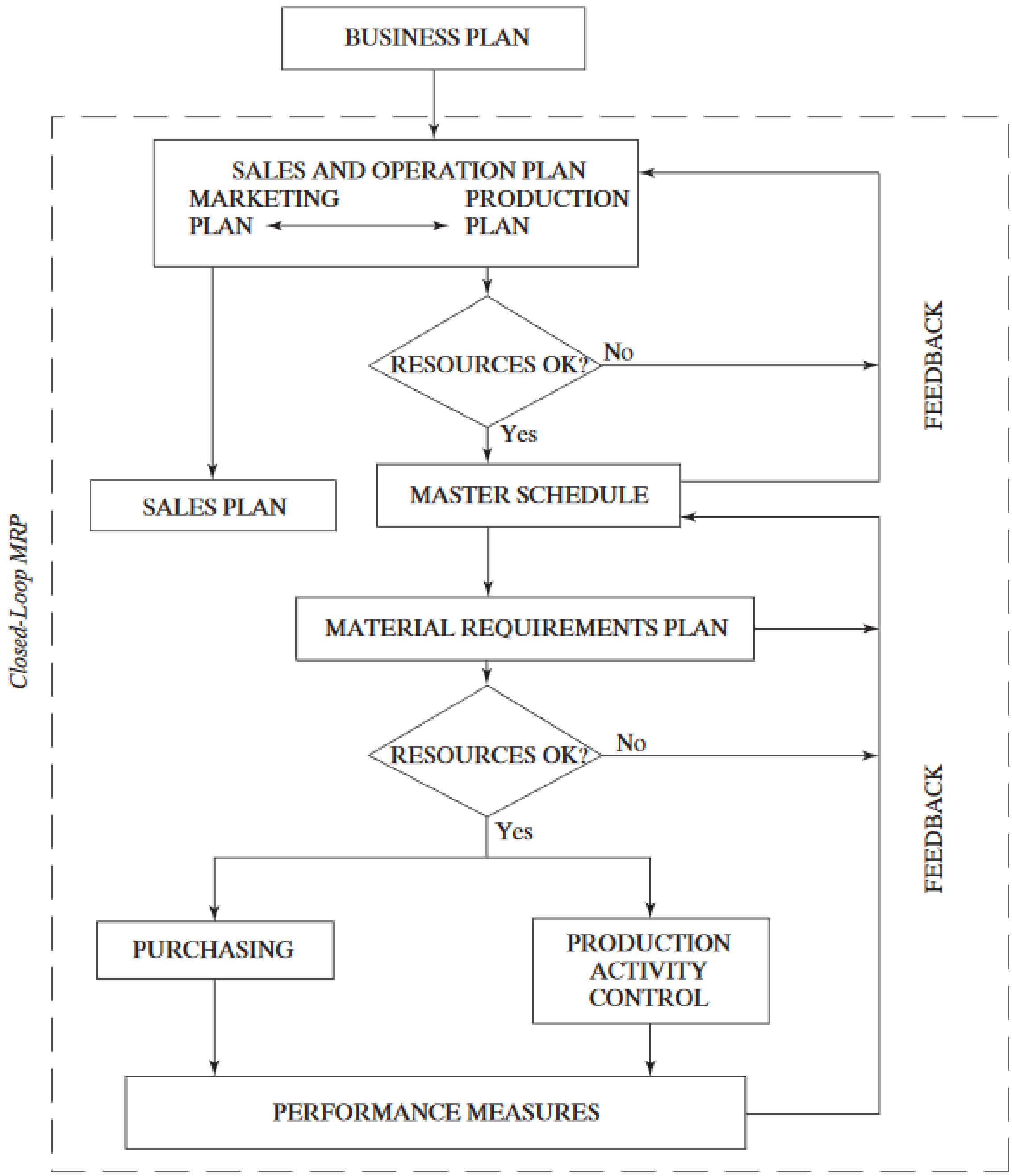

Figure 2: Manufacturing Resource Planning (MRP II) (Arnold et al., 2008)

In this paper, we are interested by the link between the strategic business plan and the Sales and Operation Plan that is illustrated by Figure 2 as well as Figure 3. To be more precise, we are mainly focusing on the link between the strategic business plan and the production plan. The reason is that we want to enable the actors of the PI's Logistics Web to plan their resources effectively to be able to fulfill demand in the forthcoming years.

As defined by Arnold et al. (2008), "the strategic business plan is a statement of the major goals and objectives the company expects to achieve over the next 2 to 10 years or more." It "provides direction and coordination among the marketing, production, financial, and engineering plans", and it is usually updated annually.

The Sales and Operation Planning (S&OP) is a process for continually revising the strategic business plan inputs (production, marketing, financial and engineering plans), usually at least updated monthly.

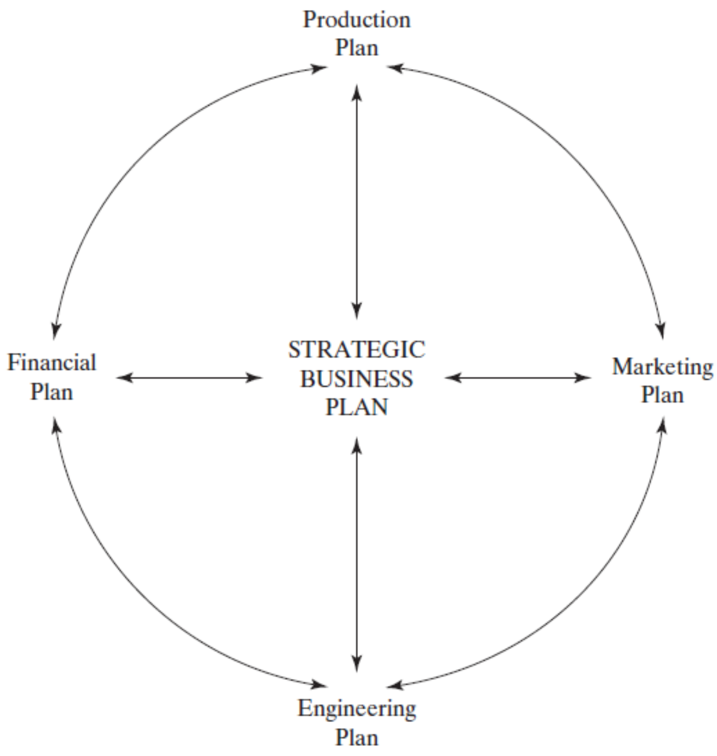

Figure 3: Strategic business plan (Arnold et al., 2008)

To ensure the feasibility of these company plans, the MRP II model organizes capacity control actions “at each level in the manufacturing planning and control system” (see Figure 2 and Figure 4), defining that “the priority plan must be tested against the available resources and capacity of the manufacturing system” (Arnold et al., 2008). Indeed, in our case, the Resource Requirements Planning corresponds to this capacity control action for the *production plan*, comparing the *production plan* to the existing resources of the company (*resource plan*).

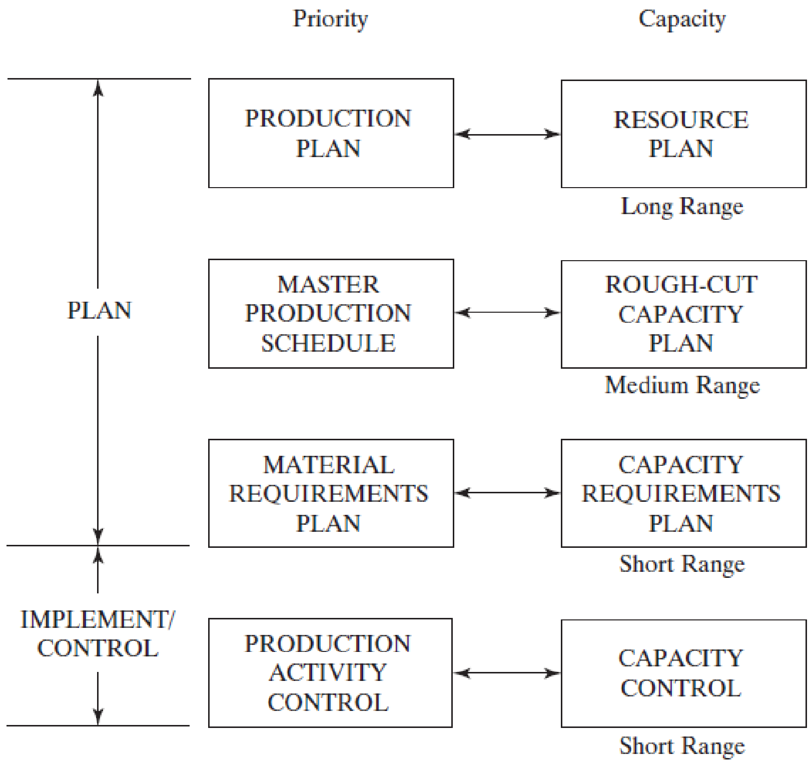

Figure 4: Production and capacity plans for each planning levels (Arnold et al., 2008)

Consequently, regarding the MRP II system, our research is focusing on the strategic planning processes for production and capacity control: Business Planning, Sales and Operation Planning, and Resource Requirements Planning. Our objective is to take advantage of these existing MRP II methodologies to enable the RRP for hyperconnected supply chains.

2.2 Research statement

To enable the RRP for hyperconnected supply chains, we will go more in depth into the MRP II S&OP and RRP processes to find out if either or not we might use these methodologies unchanged.

During their Strategic Business Planning process, every business needs to make decisions for a long-time range, often several years. This strategic Business Planning process relies on the outputs of the S&OP process: marketing plan and production plan (Figure 2 and Figure 3). Based on the marketing, production and resource plans (Figure 2, Figure 3 and Figure 4), the Resource Requirement Planning process consists in assessing if the critical resources of the company (resource plan) are well sized to respond to the global forecasted demand (from the marketing plan).

One major analysis of the S&OP process consists in identifying what is called "What-If" scenarios, corresponding to the different considered possible situations the business might have to cope with in the future (including the corresponding marketing, resource and production plans). So, these "What-If" scenarios need to be identified, calculated and analyzed in order to make good decisions.

To identify, calculate and analyze these "What-If" scenarios, businesses need first to gather their supply chain network information as well as their marketing environment information and their business potential strategic choices. Then, the following steps enable the business to establish a "What-If" scenario from the business perspective (process illustrated in Figure 5):

1. Marketing plans are deduced from the marketing environment information.
    a. A marketing plan is chosen for this scenario (including sales plan).
2. Production plans are deduced from the marketing plan.
    a. A production plan is chosen for this scenario.
3. Business resource plans are deduced from the business potential strategic choices.
    a. A resource plan is chosen for this scenario.
4. A set of supply chain network potential configurations is deduced from the supply chain network information.
    a. A supply chain network configuration (partners, production capacities, etc.) is chosen for this scenario.
5. Supply chain processes are deduced for each product that the business plans to produce according to the production plan, depending on the supply chain network configuration.
    a. A supply chain process is chosen for each product for this scenario.
6. A supply chain network production plan is deduced from the set of supply chain processes and the business production plan.

So, there is a scenario for each business marketing plan, each business production plan, each business resource plan, each supply chain network configuration, and each set of supply chain processes (with a supply chain process for each product of the production plan).

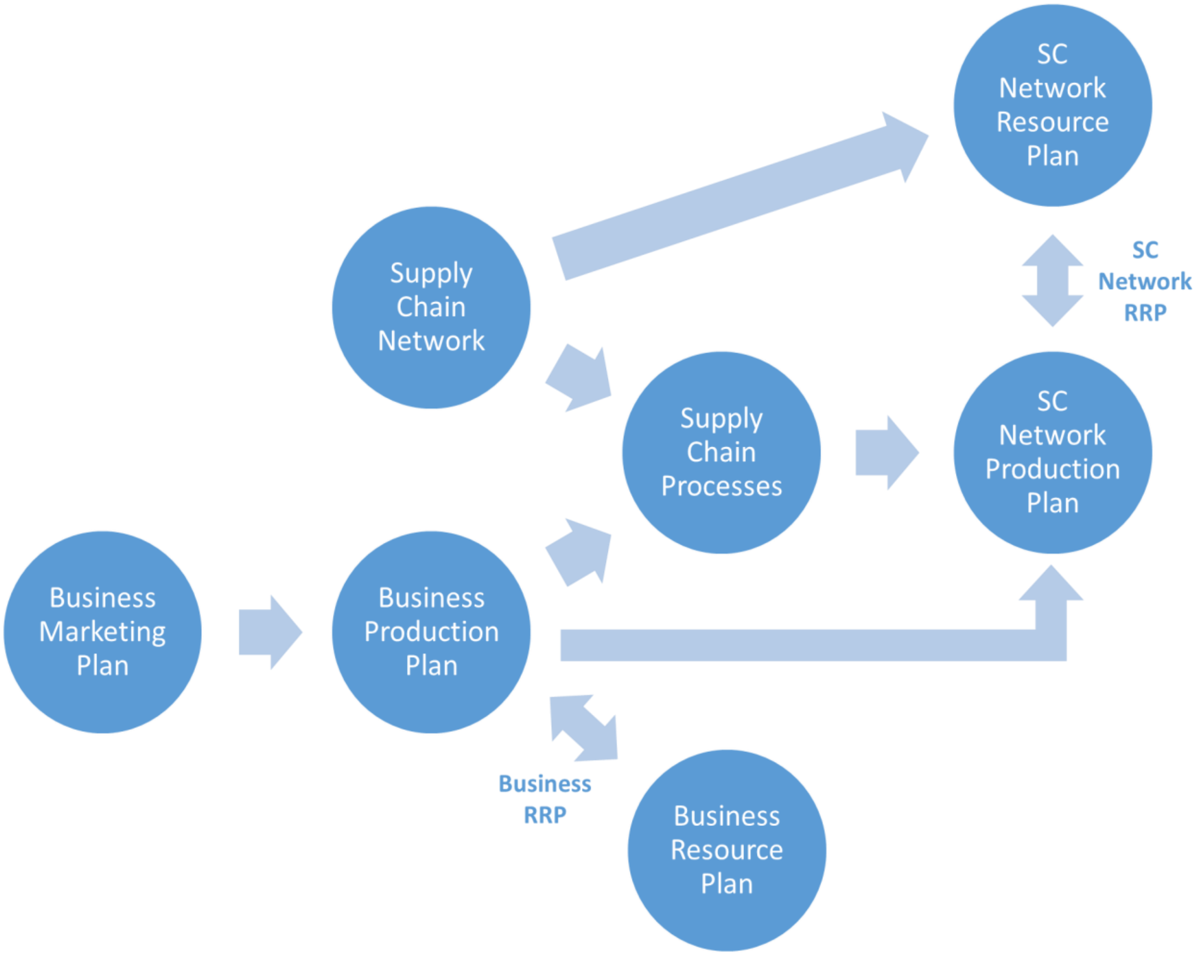

Figure 5: A process to establish S&OP "What-If" scenarios

At this point, the company identified the possible "What-If" scenarios and so can calculate and analyze them. One of the questions which can be answered from these "What-If" scenarios is: "does the business will be able to fulfil the demand in the circumstances of each scenario?" It is the RRP process which enable to answer this question using these "What-If" scenarios. Finally, having the "What-If" scenarios and their respective RRP process output will give decision makers the visibility on different possible futures with corresponding probabilities analysis, risks analysis, and even other analysis.

One of the issues identified is that this description of the S&OP is a daydreaming description. These tasks of the S&OP process are often manually achieved by supply chain engineers from the manufacturing team and by the marketing team, and can be quite complex and time consuming. Moreover, each time there is a modification in the supply chain network (new partner, new partner's know-how, new product, etc.), the list of possible supply chain processes enabling the production of each type of product might undergo several changes. In addition, with the world globalization, businesses supply chain networks are evolving quicker and quicker, and so the needs for updates of the list of possible supply chain processes are more and more frequent. In this way, businesses face the difficulty to keep their list of possible supply chain processes up-to-date, with the additional risk of mistakes during the updates. They also face the difficulty to realize an important number of "What-If" scenarios. As a consequence, businesses face the difficulty to obtain reliable, up-to-date "What-If" scenarios and their respective analysis, and in a sufficient number. The difficulty to obtain reliable scenario is also explained by the lack of communication and transparency between businesses. Companies are often building their S&OP for themselves only without having a real collaboration with their supply chain partners when building their S&OP plans.

Additionally, the MRP II system was fit for the needs of deterministic pre-established supply chains (Arnold et al., 2008; Stadtler, 2005). An explanation is that supply networks were much less volatile few decades ago than they are nowadays. With the PI, the Logistics Web enables dynamic supply chain networks whose actors may opt from spot on-demand relationships to longer-term partnerships, expanding significantly their decision space when strategically planning resources. The Logistics Web is much more dynamic than a single business centric supply chain network. Therefore, unlike MRP II system-based RRP which is done at a low frequency (such as monthly or quarterly), RRP in the PI needs to be as dynamic as the Logistics Web. In addition, unlike MRP II system-based RRP which is business centric, RRP in the Physical Internet needs to be Logistics Web centric. So, the historical MRP II system's RRP does not fit the needs of the Physical Internet: needs for a very dynamic RRP and for a Logistics Web centric RRP.

The following Figure 6 synthetize the different reasons we mentioned explaining that businesses face difficulties to take good decisions to secure their supply chains and so to ensure their capacity to fulfil the demand for a long time horizon. This figure highlight the importance for businesses of being able to build a complete and reliable set of "What-If" scenarios to ensure their capacity to fulfil the demand in the forthcoming years. Because complete and reliable scenarios enable to have a good visibility on possible futures which enables the businesses to take good decisions to secure their supply chains, which finally enables the businesses to ensure their capacity to fulfil the demand in the forthcoming years.

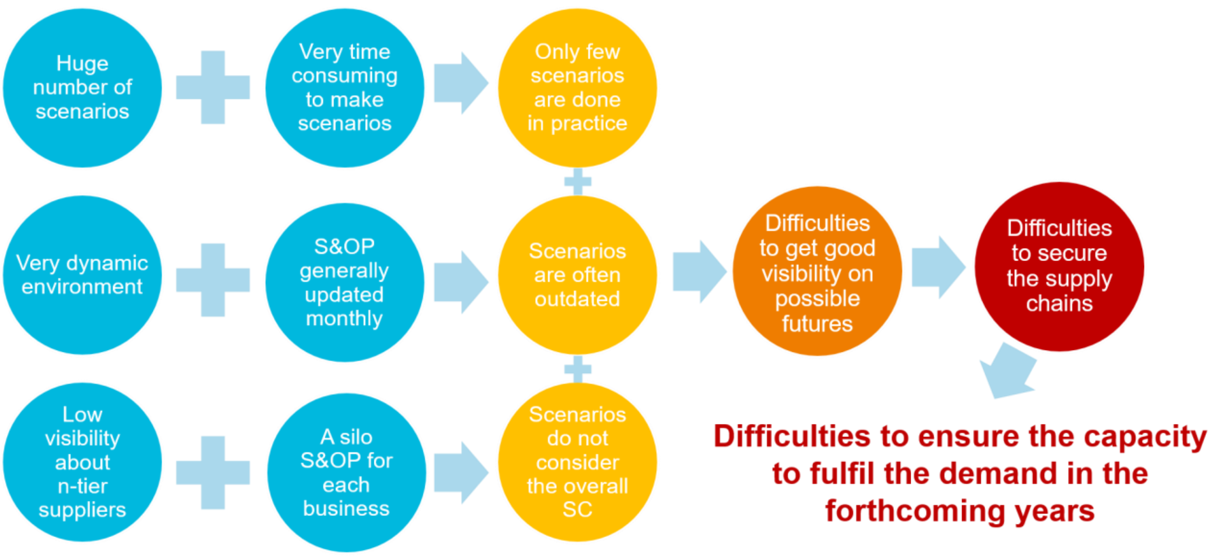

Figure 6: Some explanations of the difficulties businesses face to ensure their capacity to fulfil the demand for the forthcoming years

Consequently, there is a significant need for developing a RRP methodology adapted to hyperconnected supply chains exploiting the PI Logistics Web. As hereafter termed, PI-RRP aims to plan how the openly shared resources of Logistics Web actors are expected to dynamically support the stochastic and variable demand of the targeted supply chain in the forthcoming future. A RRP for hyperconnected supply chains to enable the actors of the PI Logistics Web to plan their resources effectively so as to be able to fulfill the demand in the forthcoming years.

3 Research agenda

We identified that the historical MRP II system's RRP does not fit the hyperconnected supply chains and so the PI Logistics Web. Therefore, to enable the actors of the PI Logistics Web to plan their resources effectively to be able to fulfill demand in the forthcoming years, we developed a Physical Internet Resource Requirements Planning (PI-RRP) methodology.

To address this PI-RRP challenge and to design the PI-RRP methodology, we take advantage of the following research works:

- IO-Suite project aiming to support interoperability of collaborative networks (Benaben et al., 2014);
- PI foundation framework (Montreuil et al., 2013);
- Methodology guidelines proposed by OGER et al. (2017) to enable supply chain agility and resilience improvement;
- MRP II methodology (Arnold et al., 2008).

The proposed PI-RRP methodology performs iteratively the following six steps:

1. Logistics Web data gathering;
2. Logistics Web modeling;
3. Available Supply Chain Processes deduction;
4. Logistics Web plan of experiments ("What-If" scenarios for load and capacity balance analysis, etc.);
5. Logistics Web risk analysis;
6. Logistics Web recommendation deduction.

Each of these steps should be designed to enable the complete automation of the methodology with the PI environment. Table 1 describes the objectives of each step of the proposed PI-RRP methodology.

Table 1: PI-RRP methodology steps and objectives

PI-RRP step	Objectives
Logistics Web data gathering	To gather information about the Logistics Web.
Logistics Web modeling	To build a model of the Logistics Web in order to enable the visualization of the situation as well as the automation of the next steps.
Available Supply Chain Processes deduction	To deduce the, hereafter defined, Available Supply Chain Processes (ASCP) on the base of the modeled Logistics Web. For each product the business plans to sell, we define the corresponding ASCP as the succession of all possible activities, enabled by the LN's partners' know-hows (abilities), which enable to produce the product. In other words, it corresponds to a unique supply chain process containing all the possible ways enabling the product production (OGER et al., 2017).
Logistics Web plan of experiments ("What-If" scenarios for load and capacity balance analysis, etc.)	To assess whether given the current set of decisions and options, the supply chain will be able to exploit the Logistics Web to have sufficient and effective production capacity to efficiently fulfil demand in the forthcoming future (load and capacity balance analysis), depending on the possible futures ("What-If" scenarios).
Logistics Web risk analysis	To evaluate the probability of each potential scenario and the corresponding risks.
Logistics Web recommendation deduction	To suggest recommendations to improve the Logistics Web, to plan the resources effectively to be able to fulfill demand in the forthcoming years.

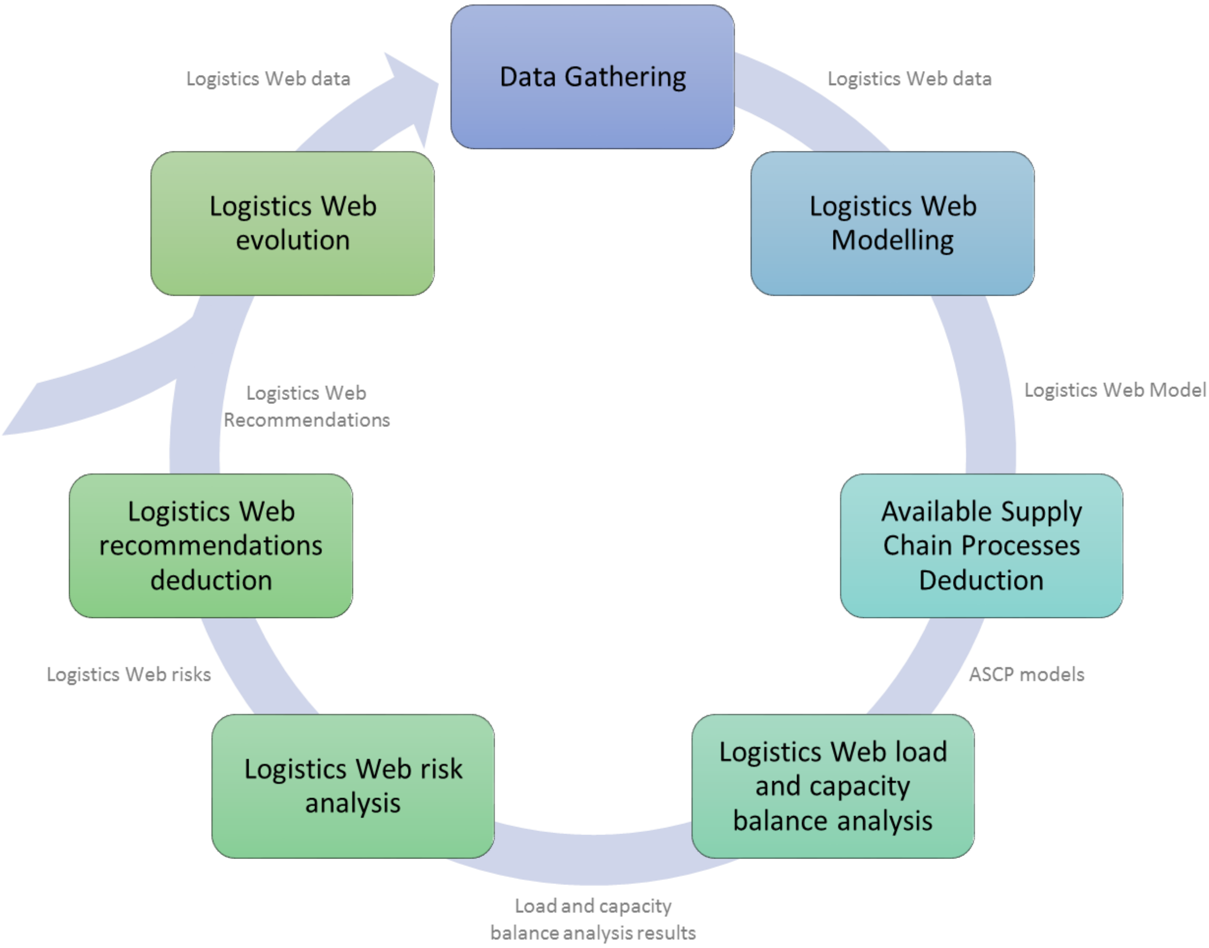

Figure 7: Physical Internet Resource Requirements Planning - Methodology proposal

4 Conclusion and perspectives

In this paper, we focused on Resource Requirements Planning (RRP) for hyperconnected supply chain, to enable PI Logistics Web actors to plan their resources effectively to be able to fulfill demand in the forthcoming years.

We explained the lack of research literature about RRP for hyperconnected supply chains. We also concluded from our literature review that the research efforts done by the PI community are focused on enabling the PI to become operational and making it efficient and sustainable, and that the PI community has not yet shown any interest in PI strategic planning.

Then, we positioned our research regarding the MRP II system's RRP, focusing on the strategic planning processes for production and capacity control: Business Planning, Sales and Operation Planning, and Resource Requirements Planning.

From the lack of research literature about RRP for hyperconnected supply chains, and the MRP II strategic planning methodology, we demonstrated the significant need to adapt this MRP II system's RRP to fit the hyperconnected supply chains requirements. A RRP for hyperconnected supply chains to enable the actors of the PI Logistics Web to plan their resources effectively so as to be able to fulfill the demand in the forthcoming years.

Finally, we introduce a Physical Internet Resource Requirement Planning (PI-RRP) methodology corresponding to our research agenda guidelines. The development of this methodology will drive our futures researches.

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