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► To cite this version:

Sanaa Tiss, Caroline Thierry, Jacques Lamothe, Christophe Rouse. Toward an agile adaptation of supply chain planning : a situational use case. 20th Working Conference on Virtual Enterprises (PRO-VE), Sep 2019, Turin, Italy. pp.344-354, 10.1007/978-3-030-28464-0_30 . hal-02290428

HAL Id: hal-02290428

<https://imt-mines-albi.hal.science/hal-02290428>

Submitted on 14 Feb 2020

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Toward an Agile Adaptation of Supply Chain Planning: A Situational Use Case

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Abstract: The project CAASC “Cloud Adaptation for an Agile Supply Chain” (French ANR project) aims to develop monitoring services in multi actors supply chain, by integrating uncertainties in supply chain planning and developing adaptation functions to environment changes.

In this paper we present a use case in the form of a serious game that aim to emerge and validate the required functionalities for the project. The game simulates a collaborative rolling horizon mid-term planning process. By analyzing its processes and results, we identify the central role of deviations analysis of plans to qualify uncertainties, assess robustness and propose response strategies.

Keywords: Collaborative supply chain planning, uncertainties and robustness, Serious game.

1 Toward an Agile Supply Chain

The CAASC “Cloud Adaptation for an Agile Supply Chain” project considers a supply chain composed of a set of entities that collaborate in the planning of flows of products, services, and finance. Each entity organizes manufacturing and distribution activities using plans managed by several decision-making centers (multi-actors). CAASC is focusing on coordination problems related to mid-term rolling horizon planning decisions across an internal supply chain.

CAASC takes advantage of three main services developed in a monitoring perspective of supply chain mid-term plans during the H2020-FoF project called C2NET "Cloud Collaborative Manufacturing Networks" [1] : i) the modeling service which uses collected data (current plans for demand, production, supply, distribution and inventories) to maintain a model of a supply chain according to a reference meta-model. ii) the detection of deviations service which compares the supply chain status model to the model expressed from the originally validated plans, and therefore detects deviations that are changing the validated plans. iii) the adaptation service which is a rule-based system that proposes adaptation processes according to some business rules and deviations characteristics.

Still focusing on the monitoring services, CAASC aims at developing new features in order to develop robustness as well as agility of the solution while taking advantage of some results of C2NET. Moreover, we are interested in deviation measurement and the interpretation of these movements to quantify and qualify uncertainties.

From a decision maker point of view, uncertainty in the uncontrollable variables of supply chain planning can induce deviations; therefore, increase the nervousness of the plans [2] [3, 4] .

Different approaches in planning uncertainty modelling are proposed in the literature. Uncertainty in the considered uncontrollable variables can be described mainly by intervals [5], probability distribution [6], [7] or fuzzy sets [8], [9], [10],[11].

Using uncertainty modeling, we aim to assess the robustness of plans, enhance anticipation and create a tradeoff between robustness [12] and agility of supply chain planning. However, the project partners belong to different domains (industrial, software developers, supply chain or artificial intelligence researchers) and they do not necessarily know totally interpret the consequences of rolling horizon planning and its related constraints. Thus, before even considering the complexity of integrating uncertainties in collaborative rolling horizon planning, an As-Is emulation was used in a deterministic context to share a user experience. We chose the serious game method for this emulation.

Serious games are known for their use in higher education [13, 14]. Furthermore, many famous serious games are used in trainings. For instance, serious games such as “Beer Game” [15] or “The Fresh Connection” [16] are a supply chain simulation game where the main functions of the company are represented. Serious game has also been used to analyze the dynamic decision-making process in supply [17].

In our case, we chose the serious game method for other reasons, mainly to:

- enable industrial partners to validate a use representative case situation,
- frame the research topic and identify the problems related to the collaborative planning within a rolling horizon process,
- share competences and points of view of the different users,
- allow partners to project themselves into decision-making and validate needs and specifications in terms of agility and robustness evaluation,
- formalize a use case that can be retested to assess the proposed functionalities.

A collaborative approach with the partners of the project (end user, software company, research laboratories) has been adopted to design the serious game. Starting by an industrial interview and a survey on APICS as a reference of planning processes modeling, the collaborative mid-term planning processes was modelled. Then, were defined the components of the game simulating the dynamic of those processes and the physical flow related to the game. After that, in a prepared environment the game was run, and results were collected. Finally, the results issued from the game were analyzed and the main problems and requirement were identified in terms of agility and CAASC functionalities development.

2 Process Under Study

2.1 Industrial Case and APICS Process

The project will provide use cases that come from an analysis of Pierre Fabre Dermo Cosmetics (PFDC) company processes. A series of interviews took place in order to understand the actual process of planning and collaboration between different partners in the supply chain (Fig. 1).

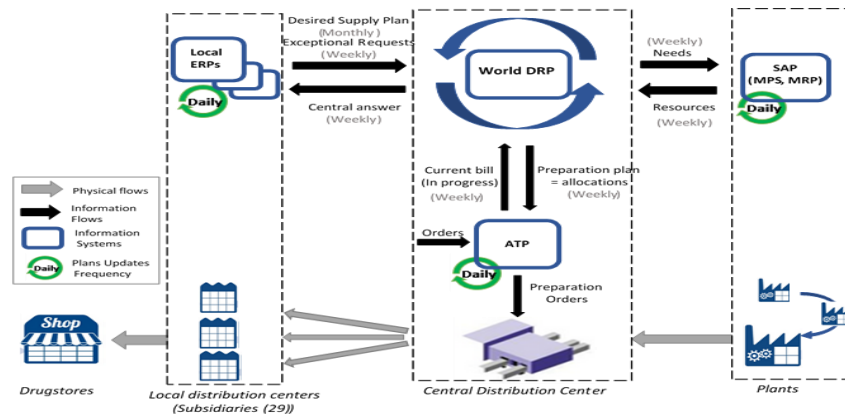


Fig. 1. PFDC Supply Chain (tactical level).

PFDC supply chain is composed of the following stakeholders: suppliers, manufacturing plants (in France), Central Distribution Centre (in France), local subsidiaries or partners and final customers (drugstores) all over the world [18].

Within CAASC, PFDC supply chain supported by a cloud platform links its various actors. The supply chain is a collaborative network of actors that use the platform in order to perform their collaborative planning process.

Production is stored in a central warehouse in France before being distributed to subsidiaries and partners. PFDC is always trying to improve its performances in terms of service. Aligning the plans of the supply chain partners, agile deployment of stocks and the optimization of the distribution of inventories among the subsidiaries are the primary objectives.

In the context of this industrial case, APICS[19] is our reference to model a generic collaborative planning process.

Considering the supply chain described in the figure 1, subsidiaries planners, a supply planner and a production planner are the partners collaborating in the supply chain planning. The master plans exchanged between partners are mainly: Sales and Operations plans, Distribution Requirement planning, Master Production Scheduling [19].

Planning changes are limited by the time fences and delivery time. "Changes that are far off on the planning horizon can be made with little or no cost or disruption to

manufacturing, but the nearer to delivery date, the more disruptive and costly changes will be.” [19]

In the frozen zone, planning changes are not allowed and required the approval of the decision maker in case of emergency. The slushy zone is a tradeoffs zone, downward demand (conv. Upward production) request is automatically accepted while the upward demand (conv. Downward production) must be confirmed by decision makers. Finally, in the liquid zone the changes are automatically accepted and usually done by the computer within the defined limits of the plans.

2.2 Collaborative Planning Process

The figures 2 below details the inputs and outputs (decisions) of every planning related to each partner in the supply chain and for each level of planning. Four steps are identified in the planning process and three different decision makers are concerned:

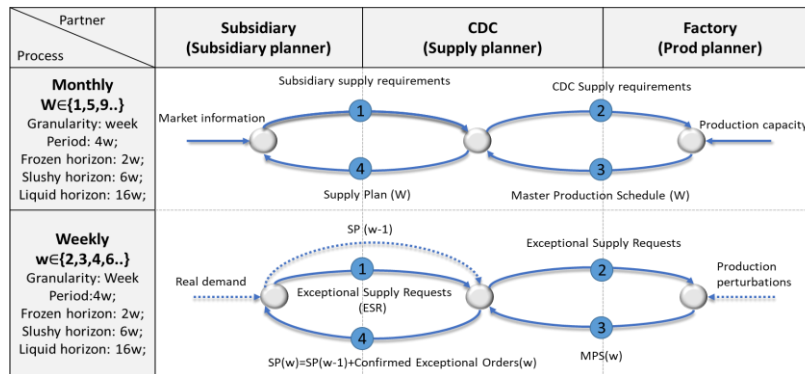


Fig. 2. Collaborative supply chain planning process

Each subsidiary elaborates its sales forecast and define its supply requirements. The confirmed requirements present the desired supply plan from the Central Distribution Center. Each subsidiary order on its own without regard for the available inventory of the distribution center neither the requirements of other subsidiaries nor the production schedule. However, the supply planner in the CDC has the richest view on all the independent supply chain system (SAP, world DRP) due to his position as coordinator and CDC resource manager in the supply chain.

We make the difference between two levels of planning process. The monthly planning process and the weekly one.

Monthly, in the first week of the month, the requirements of the different subsidiaries are consolidated to become the base of supply chain resources dimensioning for the current month. The resulted plans of this process are the reference of the rest of the month.

Every week, the DRP and MPS master plans are reviewed and can be changed in case of perturbations. We consider perturbations related to the occurrence of a set of events mainly: Demand variation (real sales); Subsidiaries exceptional requests (promotion, shortage...); Quality control problem (rejection of products, high control

time...); Operational production problem (breakdowns, closure, schedule changes, order splitting or aggregation, ...); Transportation problems (lost products, customs delay).

Regarding time fences, it was identified a planning horizon of 24 weeks including a frozen horizon of 2 weeks plus delivery time, slushy horizon of 6 weeks and liquid horizon of 16 weeks.

2.3 Supply Chain Planning Process Analysis

A deterministic supply chain planning is considered. The variables of supply chain planning such as lead time, costs and other system parameters, are considered known with certainty. In a decision process (weekly or monthly), depending on his role, each decision maker receives, decides and sends plans (forecast, requirement, supply, capacity). The received plans are uncontrollable variables on which uncertainty could be modelled. Conversely, the sent plans become uncontrollable variables for other deciders.

In a rolling horizon planning context, deviations are a set of differences between the weekly and the monthly reference for a same plan. In the operational level, deviations present the difference between the planned and the realized quantities. On received plans deviations enable to qualify uncertainty. On decided and sent plans, deviations enable to qualify robustness of service rate and nervousness.

3 A serious Game as a Proof of Concept

3.1 Game Description

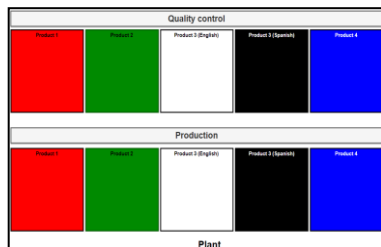


Fig. 3. Plant game board

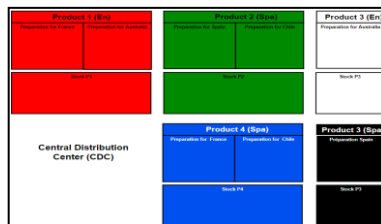


Fig. 4. CDC game board

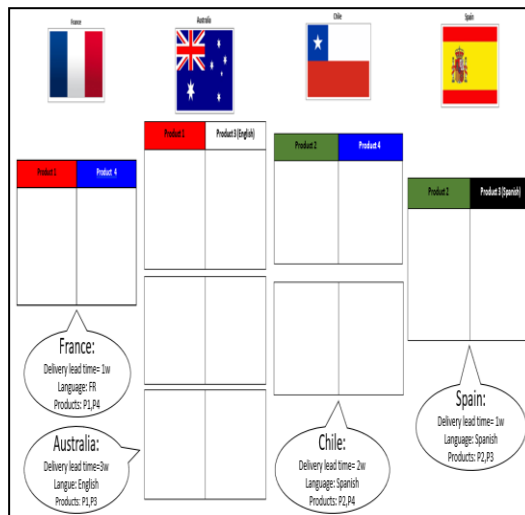


Fig. 5. Subsidiaries Game board

To best simulate the modelled supply chain planning process while having consistent results, the serious game was sized as follow:

- 4 subsidiaries (France, Australia, Spain, Chile); 1 CDC; 1 factory.
- 5 Products: P1 (English), P2 (Spanish), P3 (Spanish), P3 (English), P4 (English). Products are different according to the packaging language. French is a default language in packaging. In order to avoid a shortage, P3 (Spanish) can be sent to Australia and conversely P3 (English) to Spain or Chile.

The game board is designed as shown in Fig. 5, Fig. 6, Fig. 7.

In addition to the board game, Excel sheets have been designed as a planning decision support enabling to keep a written record of the game. These sheets are shared on a platform allowing the simultaneous modification of the data. Each decision view is a worksheet [17].

| Product code | Process type | Semaine | Data | | | | | | | | | | | | | | | |
|------------------------|-------------------------------------|--|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------------|------------|-------------|-----|
| | | | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | W11 | W12 | | | | |
| P1 | Monthly; Computer; Decision 2; W1 | France Supply Requirements(W1) | 30 | 70 | 60 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | |
| | | Australia Supply Requirements(W1) | 20 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| | | Objective stock | 230 | 210 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 210 | 228 | 238 | 240 | | | |
| | | MPS(W0) | 110 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 110 | 118 | 120 | 120 | | | | |
| | | CDC Supply Requirement | 110 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 110 | 118 | 120 | 120 | | | |
| | Monthly; Decision 3; W1 | Projected stock | 170 | 230 | 210 | 200 | 200 | 200 | 200 | 200 | 210 | 228 | 238 | 240 | | | | |
| | | MPS (W1) | 110 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 110 | 118 | 120 | 120 | | | | |
| | | Projected stock, MPS(W1) | 170 | 230 | 210 | 200 | 200 | 200 | 200 | 200 | 210 | 228 | 238 | 240 | | | | |
| | | Supply Plan, France (W0) | 30 | 70 | 60 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| | | Supply Plan, France(W1) | 30 | 70 | 60 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| | Monthly; Decision 4; W1 | France Project Stock(W1) | 140 | 140 | 160 | 110 | 100 | 130 | 110 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | | Supply Plan, Australia (W0) | 20 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| | | Supply Plan-Australia(W1) | 20 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| | | Australia Project Stock(W1) | 140 | 110 | 90 | 70 | 40 | 30 | 70 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | | Supply Plan(W1) | 50 | 120 | 110 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 110 | 118 | | |
| | Weekly; Computer; Decision 2; W2 | Stock CDC, proj. Supply Plan(W1) | 170 | 230 | 210 | 200 | 200 | 200 | 200 | 200 | 210 | 228 | 238 | 240 | | | | |
| | | Supply Plan, France (W1) | 70 | 60 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| | | Except. Supply Requirement, France (w2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Supply Plan, Australia (W1) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| | | Except. Supply Requirement, Australia (W2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Weekly; Decision 3; W2 | MPS (W1) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 110 | 118 | 120 | 120 | | | | | |
| | Except. CDC Supply Requirement (W2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | CDC projected stock | 230 | 210 | 200 | 200 | 200 | 200 | 200 | 200 | 210 | 228 | 238 | 240 | | | | | |
| | MPS (W2) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 110 | 118 | 120 | 120 | | | | | |
| | Stock, CDC, proj. MPS(W2) | 230 | 210 | 200 | 200 | 200 | 200 | 200 | 200 | 210 | 228 | 238 | 240 | | | | | |
| Weekly; Decision 4; W2 | ESR, France | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Supply Plan, France(W2) | 70 | 60 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | |
| | France projected stock(s) | 140 | 160 | 110 | 100 | 130 | 110 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | |
| | ESR-Australia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Supply Plan-Australia(W2) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | |
| Computer Calculation | Australia projected stock(W2) | 110 | 90 | 70 | 40 | 30 | 70 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | |
| | Supply Plan(W2) | 120 | 110 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 110 | 118 | | | |
| | Stock CDC, proj. Supply Plan(W2) | 230 | 210 | 200 | 200 | 200 | 200 | 200 | 200 | 210 | 228 | 238 | 240 | | | | | |
| | System status | Decision | Data (previous plans, other partners decisions) | | | | | | | | | | | | Frozen zone | Slusy zone | Liquid zone | |

Fig. 6. Extraction from the supply planner view (planning of week1 and 2)

Every decision view is enriched by a set of the decision support tools. They are as follows:

- The projected stock presents the impacts of every decision on stocks with significant colors: Orange in case of a planned consumption of the objective stock and red in case of a planned shortage.
- The previous plans and the current ones can be compared to highlight the deviations and the executed modifications.
- The proposed plans are automatically calculated from the available data.

In accordance to the supply chain planning process, a role sheet exists for each player (Subsidiary planner, supply planner, production planner). Furthermore, a game master has been designated to manage the time of the game and the stocks of other subsidiaries (other than France) and to announce predefined disturbance cards for other players. Finally, a test session has been conducted with CAASC project partners. The processes (Fig. 7, Fig. 8) below describe how the session unfolds:

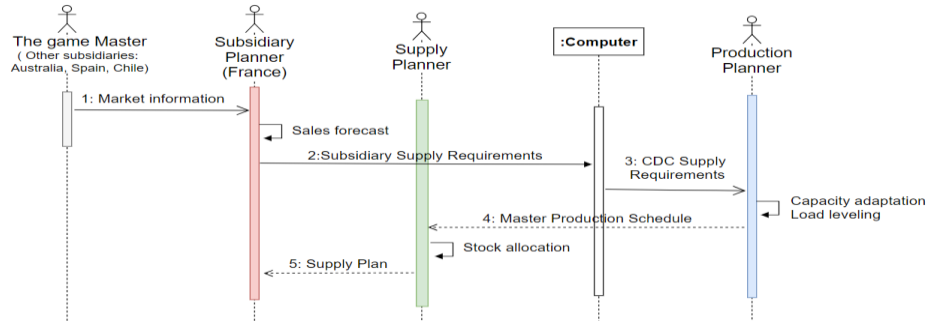


Fig. 7. Decisions flow: monthly supply chain process

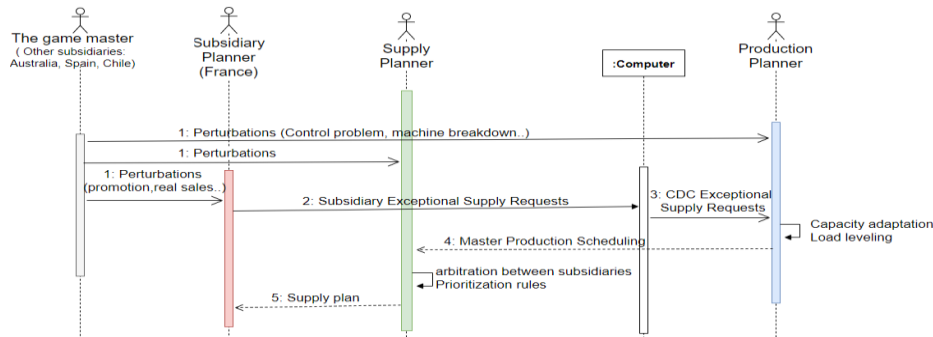


Fig. 8. Decisions flow: weekly supply chain process

3.2 Game Analysis

The game was played once for one supply chain. Authors played the role of the game master and informed subsidiary players about real demand, market changes and production perturbations.

By the end of the game session, two types of analysis of plans on the rolling horizon are performed: (i) The plan deviation measures the difference two successive plans; (ii) the planning error measure the difference between the planned and real (demanded or delivered) quantities.

In the following, the analysis focuses on the relation between one subsidiary (France) and the Central Distribution Center (CDC) and product P1.

Table 1. Scenario of the game for product P1

| Week | Network echelon | Scenario (perturbations) |
|------|-----------------|---|
| 1 | No one | Everything is normal and in line with the forecast. |
| 2 | Subsidiary | Sales vary from ± 10 compared to forecasts. |
| 3 | Subsidiary | Registered sales compared to forecasts: Australia (-10 P1), France (+20 P1). |
| 4 | Subsidiary | Registered sales compared to forecasts: Australia (+10 P1), France (-40 P1). |
| 5 | Subsidiary | In France: promotion on product P1 on weeks 10 to 14. A doubling of sales is planned on the period. 80% of the sales increase are an anticipation of sales originally forecasted on weeks 15 to 20. |

Table 2. Deviations of Supply Requirements (France;P1) = $SR[w](t) - SR[w-1](t)$.

| Week | t2 | t3 | t4 | t5 | t6 | t7 | t8 | t9 | t10 | t11 | t12 | t13 | t14 | t15 | t16 | t17 | t18 |
|------|----|----|----|-----|-----|-----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| w2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| w3 | | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| w4 | | | 20 | 20 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| w5 | | | | -10 | 30 | 100 | 40 | 50 | 50 | -30 | -30 | -20 | -10 | -10 | 0 | 0 | 0 |
| w6 | | | | | -30 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 3. Deviations of Supply Plans (France;P1)= $SP[w](t) - SP[w-1](t)$.

| Week | t2 | t3 | t4 | t5 | t6 | t7 | t8 | t9 | t10 | t11 | t12 | t13 | t14 | t15 | t16 | t17 | t18 | t19 |
|------|----|----|----|----|----|-----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| w2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| w3 | | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| w4 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| w5 | | | | 0 | 0 | 100 | 40 | 50 | 50 | -30 | -30 | -20 | -10 | -10 | 0 | 0 | 0 | 0 |
| w6 | | | | | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 4. Supply Requirements Error = $SR[w](t) - SRt$.

| Week | t2 | t3 | t4 | t5 | t6 |
|------|----|-----|-----|-----|----|
| w1 | 0 | -10 | -20 | -10 | 0 |
| w2 | 0 | -10 | -20 | -10 | 0 |
| w3 | | 0 | -20 | -10 | 0 |
| w4 | | | 0 | 10 | 0 |
| w5 | | | | 0 | 30 |
| w6 | | | | | 0 |

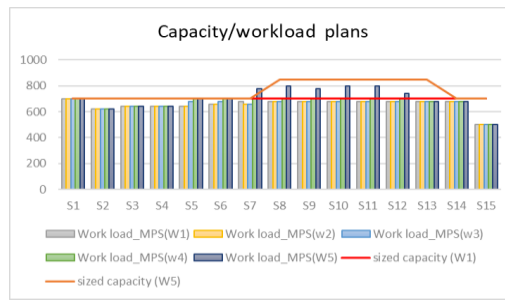


Fig.9. Production capacity/workload analysis

In table 2 and table 3, the deviation on Supply Requirements (request from subsidiary) and on Supply plan (answer of CDC) make easier the analysis of the propagation of information within the supply chain. In yellow, appear the Supply Requirement deviations that are requested by the subsidiary within the frozen horizon and not accepted by the CDC. These requests appear to mitigate errors between the subsidiary last forecast and the real customer demand he faces. In week 5, the subsidiary is informed of a promotion (see table 1). In orange in table 2 and table 3, appear the impact of the promotion information on the supply requirements.

In red in table 2 and table 3, appear the process of request and acceptance of a change: it is first requested on week 3 on period t3 in SR, accepted in week 3 on t8 in SP, and maintained at week 4 on t8 in SR.

In figure 9, the propagation of the above variation till the factory is depicted. The initial sized capacity was 700 products per week, the amount requirements received from the CDC increase the workload, and the production planner decide to resize the capacity in the week 5 (first week of the second month) to become 850 for the weeks 8 to 12.

In table 4, the supply Requirement error is shown for weeks 2 to 6. This error can hardly be interpreted according to the game scenario. But it shows the imprecision of the plan.

This user experience enabled to validate the following requirements for the uncertainty integration :

- characterization of the uncertainties undergone by a decision-maker by analyzing deviations and variations in deterministic plans along a rolling horizon. Machine learning tools will be used to well characterize this uncertainty from data collected from the industrial case,
- categorization of products according to the type of uncertainty,
- consideration of uncertainties in the uncontrollable variables to develop and enrich a user decision support interface,
- evaluation of user decisions (plans) in terms of robustness and stability against different disruption scenarios.

4 Conclusion and Future Works

The game simulates the production and distribution of cosmetics supply chain reproducing the current functioning of PFDC planning. It reproduces 2 planning processes: a monthly that starts from sales forecasts to size the resources of the supply chain and a weekly process to adjust plans based on requests in case of perturbation. This version will allow us in the future to implement the complete Serious Game, confronting this time the current and future processes that integrate the functionalities of the project CAASC while considering uncertainty in planning parameters.

The planning errors (difference between scheduled quantities and the real demand (or the real deliveries)) will be the basis for characterizing uncertainties. Otherwise, the plans deviations through the rolling horizon (deviations between successive plans) allow to better isolate the perturbations and their propagation in the supply chain which will enable to make the uncertainties explainable.

The serious game session, as a user experience, enabled partners to validate the required functionalities for the project in terms of uncertainty modelling and integration of uncertainty models in the user decision support interface.

Acknowledgement

Authors want to acknowledge ANR for the funding of the CAASC project.

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