1

From Advanced Planning System to Advanced Budgeting System: The Next Step in Supply Chain Management Software

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1. Introduction

A supply chain (Beamon, 1998) is traditionally characterized by three types of flow:

- The forward physical flow (purchase of materials, transformations of the raw materials into products, delivery of the products). The physical flow optimization aims to satisfy the final customers.
- The backward financial flow which circulates in a discontinuous way. The financial flow optimization is made in a local way, in each supply chain link, but seldom in a global way. The financial flow optimization (Badell et al., 2005) will make possible the shareholders satisfaction and the supply chain working improvement.
- The backward information flow which allows the coordination of financial and physical flow between each node, and the global supply chain coordination.

The paper objective is to propose an approach to evaluate logistic process performance in supply chain by discussing connections among the physical and the financial flows across the chain. Judging from the literature, these flows do not always overlap in supply chain management. If there are some works which propose to analyse the impact of physical flow in financial flow in strategic planning (Vidal and Goetschlackx, 2001), very few works show relationships between cash position and planning in tactical or operational dimension. A study of supply chain manager interest for integration of financial impact in operational and tactical planning is done by (Vickery et al., 2003): these authors show that managers are really interested by tools which integrate financial and customer aspects in optimization. Despite their real interest, this kind of tools does not yet exist.

Hence, the challenging problem consists in formalizing relationships between physical and financial flow by their integration in planning processes for an internal supply chain (a company supply chain). Our aim is to propose an approach which allows the use of budgeting in production planning with Advanced Planning System (APS) tools for company supply chain. Indeed, in actual APS, operational and tactical plans do not integrate financial resources synchronisation, as described in figure: financial metrics are only translated in physical metrics such as stock level for example.

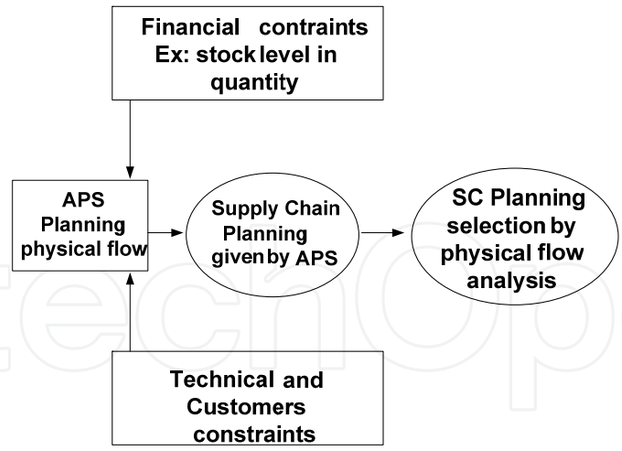

Fig. 1. Actual process of tactical planning selection in APS

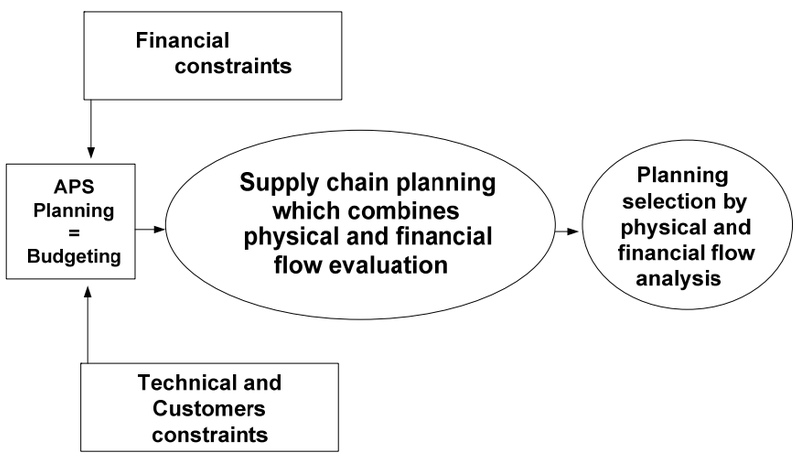

Fig. 2. Towards a planning selection in APS thanks to physical and financial flow evaluation

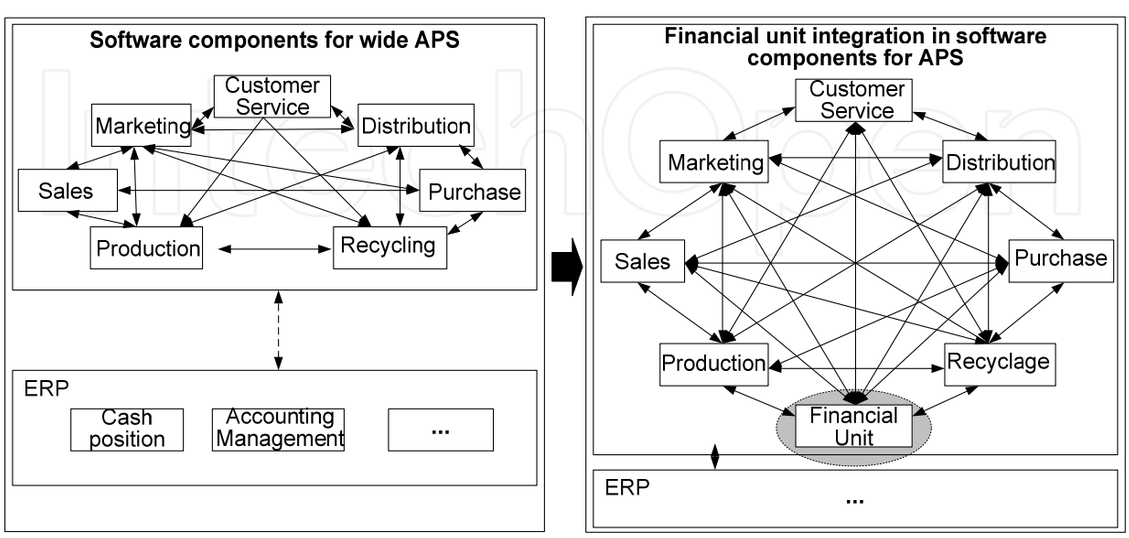

Fig. 3. Financial unit integration in software suite for supply chain management

This paper proposes to integrate financial metrics in APS. We assume that budgeting and planning financial and physical flows could be synchronised. This kind of synchronisation can be seen as a performance driver for supply chain management. By integrating financial parameters such as payments terms in Activity Based Costing models and coupling this type of model with computer models for planning, each production plan will be associated with a budget and with financial metrics.

The paper is organized as follows: next section present a brief state of the art about integrated decision making software for supply chain management. An interoperable and multi flow decision making tool software, called Advanced Budgeting System is proposed in section 3. Section 4 presents computational results based on the ABS used in a case study. Finally, some conclusions are given in section 5.

2. State of the art and problem description

Most part of the authors who propose to study financial flows in supply chain management focus on cost models such as Activity Based Costing. Activity Based Costing was introduced by Cooper (1991). If theoretical works are done on ABC modelling and supply chain management (Senechal and Tahon, 1998), (Hombourg, 2004), (Boons, 1998), (Bih Ru and Fredendal, 2002), very few works deals with ABC using in Supply Chain production planning evaluation. Connections of tactical production planning and ABC are presented by (Schneeweiss, 1998) and (Ozbaayrak et al., 2004). The aim of their work is to evaluate production strategies in flexible manufacturing system thanks to ABC tools, not to evaluate supply chain planning. ABC evaluation is not a financial flows evaluation because payment delay and depreciations are not taking into account: therefore, this evaluation only deals with costs and not cash management problem, which is a very important parameter in enterprise financial evaluation in tactical level.

The main objective of cash manager is to have enough cash to cover day-to-day operating expenses but also to have the fewest excess cash because it is not a productive asset. By having excess cash in account, a company loses the potential interest (an opportunity cost) generated by investing money in securities. This implies that firm has to maintain a balance between amount of cash sitting in account and cash invested in securities. Cash management problem was simply formulated by Baumol (1952) as an inventory problem assuming uncertainty (Miller and Orr, 1966). Two types of metrics are generally used to optimize financial flow: cash position which reveals the cash which is available in the end of a period and cash flow which reveals cash generation during a period. In a recent paper, (Badell et al., 2005) optimizes financial flow and cash position in the end of each period. To our knowledge, as shown in table 1, there are very few scientific works which integrate financial aspect and physical aspect in a simultaneous way operational, tactical and strategic planning for supply chain.

To conclude this section, table 2 presents a study (which is not exhaustive) which evaluates the most important APS software editors. For each APS, we study if financial flow is integrated with physical flows optimization. Note that some of the tested APS have links with ERP but these links do not integrate financial evaluation with planning. Moreover, discrete event simulation are not used by APS which only use optimization tools.

Authors	Horizon level			Studied Flow	
	Operational	Tactical	Strategic	Physical flow	Financial Flow
Badell et al. 2005		X		X	X
Baumol, 1952	X	X			X
Bertel et al., 2009	X			X	X
Brown and Haegler, 2004	X	X			X
Cattani and Souza, 2001	X	X			X
Comelli et al, 2008		X	X	X	X
Comelli et al 2009	X	X		X	X
Girlich, 2002	X	X			X
Graham and Harvey, 2001		X			X
Gul, 2001			X	X	X
Hendricks and Singhal, 2003			X	X	X
Inderfurth and Schefer, 1996	X				X
Miller and Orr, 1966	X	X			X
Orgler, 1969		X			X
Premachandra, 2003			X	X	X
Rink et al., 1999			X	X	X
Salameh et al., 2003			X	X	X
Vidal and Goetschlalx, 2001			X	X	X
Wang, 2002		X		X	X

Table 1. Cash management formulation and supply chain management: a state of the art

	Dataware House	Process Modelling	Physical flow Opti-mization	Budgetary Develop-ment	Discrete event Simulation
Not specialized tools ADEXA iCollaboration Suite ; ASPEN eSupply Chain Suite ; FUTURMASTER Futurmaster; ORACLE aps; PEOPLE SOFT SupplyChain Planning; SAP Advanced Planer and Optimization (APO); SYNQUEST One2One Solutions.	Not Specified	Yes	Yes	No	No
Specialized tools SIB Sextant; KEYRUS K@-prim; MC KESSON Evoluance SIAD...	Not Specified	Yes	Not specified	No	No

Table 2. APS functionalities

If supply chain managers want to plan and budget activities as a whole, they must use software which permits a real integration of supply chain informational, physical and financial flows. This kind of software does not actually exist. Next section proposes a software concept which takes into account physical and financial flows in decision making modelling.

3. Avanced Budgeting System proposal

It is worth noting that there is a need for general approach for both supply chain modelling and evaluation which combines data from physical, informational and financial flow in one type of software which is a global Advanced Planning Systems. This one allows solving supply chain planning problems with an integration of all the system flows. Advanced Budgeting System is the chosen name for this software concept. Supposing that the "budgeting" activity for financial flow is the equivalent of the planning activity for physical flow, an advanced budgeting system is defined as a coherent succession of software applications allowing optimization and evaluation of supply chain physical and financial flows. This software combines physical and financial flows for the whole chain as for an entity with strategic, tactical and operational levels. These various applications are connected to the information system of supply chain entities by a data warehouse which reprocesses heterogeneous data resulting from different software applications in order to combine prescriptive and descriptive models data. Usually, prescriptive models are used in APS for decision making (Dietrich, 1991): they are used to make a choice on the design, control or functioning of supply chain, while descriptive models make it possible to evaluate decision made by prescriptive model or directly by actors.

Figure 4 shows the ABS characteristics and the connexions between the various supply chain activities and flows.

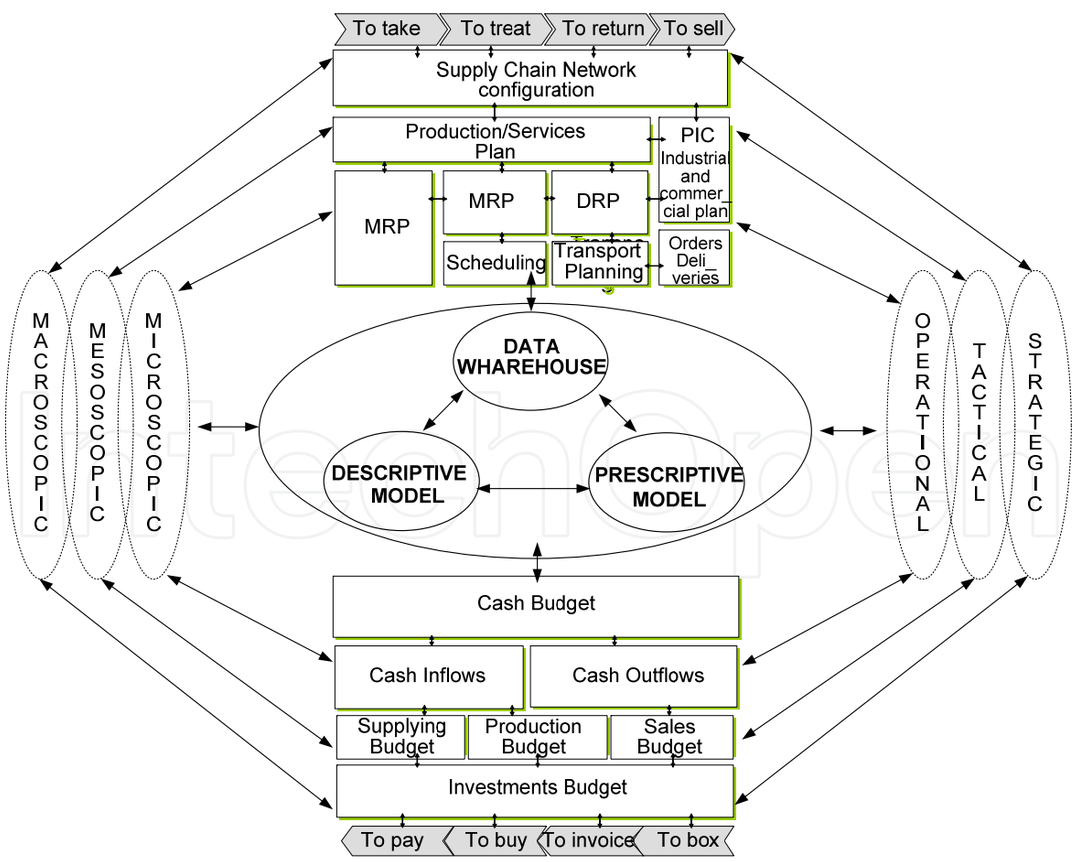

Fig. 4. Advanced Budgeting Context.

Technical and conceptual features of an ABS are given in table 3. If the context (figure 4) of an ABS use is the same than an APS , software functionalities integrate activities budgeting with planning. An ABS can be used for a complex system of the supply chain (a factory, a business unit…) as for the whole supply chain. ABS contains a decisional module which organises information for supply chain managers with balanced scorecards (Kaplan, 1992).

	Advanced Planning and Scheduling	Advanced Budgeting and Scheduling
Context	Internal and external Supply Chain	Internal and external Supply Chain
Functionalities		
Network Design	For physical flow	For physical and financial flows
Distribution (DRP)	For physical flow	For physical and financial flows
Production (PDP)	For physical flow	For physical and financial flows
Supplying (MRP)	For physical flow	For physical and financial flows
Scheduling and transport	For physical flow	For physical and financial flows
Decisional Tools Performance Measurement	Some physical flow metrics	Balanced Scorecard+ PREVA model (Comelli et al., 2008)
Connection with the chain entities information system	Not detailed	Data warehouses allowing collection of data and information from heterogeneous applications
Software components for decision making tools	Optimisation (Cplex) and heuristics	Coupling of optimisation/ simulation (prescriptive and descriptive models)
Collaborative Planning	Collaborative planning gives to the chain entities the quantity of products and services to be produced and delivered on short, medium and long term for a given customer satisfaction rate.	Collaborative planning gives to the chain entities the quantity of products and services to be produced and delivered on short, medium and long term which gives the highest level of value for Supply Chain entities.

Table 3. ABS characteristics.

Financial flow can be evaluate thanks to PREVA models (PREVA means PROcess EVAluation (Comelli et al., 2008)) which makes it possible to translate in a prospective and causal way the impact of physical flows in supply chain financial flows. PREVA gives the possibility, thanks to ABC models and cash flows models to evaluate supply chain running.

Collaborative plannings resulting from ABS allows, for a level of customer satisfaction to choose the solution / the planning which generates the most value for the supply chain.

A case study, which presents, thanks to PREVA approach improvement, the interest of ABS software is detailed in next section.

4. Avanced Budgeting System use

To illustrate the approach presented in previous sections, a industrial case study, adapted from a real industrial application done in Clermont Ferrand Computer Laboratory is presented in first paragraph. An example of an ABS which was built for this case study is given in paragraph 2. Scorecards and results are given in paragraph 3.

4.1 Case study presentation

The company supply chain, called M (a tyre manufacturer) is comprised of 6 Business Units, called B1, B2, B3, B4, B5, B6. Six families of product, called P1, P2, P3, P4, P5, P6 are manufactured in the system. Figure 5 presents the supply chain infrastructure.

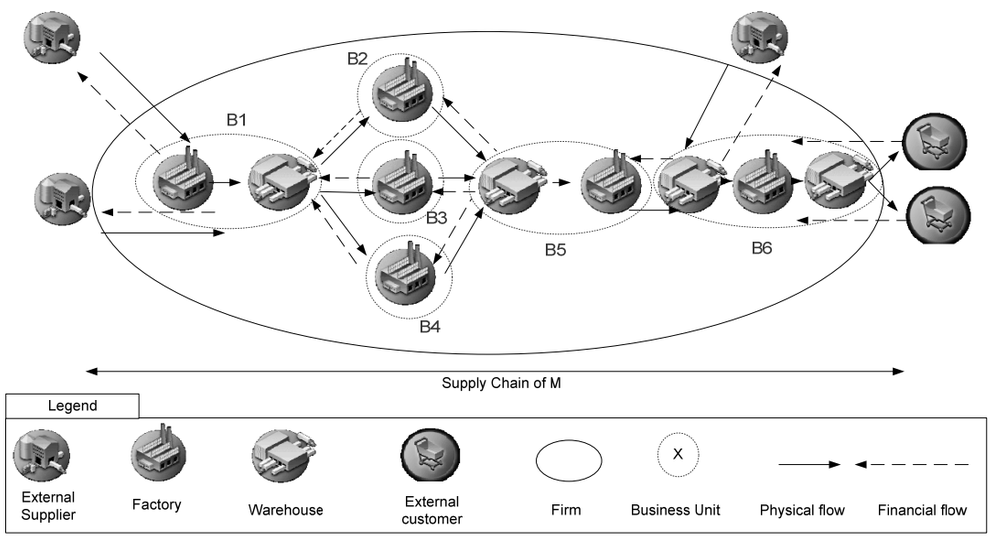

Fig. 5. Supply chain structure

This Company Supply Chain is shared in four steps. In first step, one business unit called B1 is considered. In step 2, B2, B3, B4 are working both together and have exactly the same structure. In step 3, product from B2, B3, B4 are manufactured in B5 on a special plateform. This type of plateform gives the product its name and its quality. In step 4, B6 products are prepared for european, asian, american markets. M logistic processes are as follows:

i. B1 is made up of a factory and a logistic platform in which products are stocked;
ii. B2 is made up of one factory;
iii. B3 is made up of one factory;
iv. B4 is made up of one factory;
v. B5 is made up of one logistic platform and one factory. Products from B2, B3, B4 are stocked in B5 logistic platform before being transformed in B5 factory;
vi. B6 is made up of two logistic platform and one factory. The first B6 logistic platform, which is implanted before B6 factory stocks products from B5 and from external

suppliers. The second B6 logistic platform, which is implanted after B6 factory stocks final products;

- Distribution Requirement Planning(DRP) is done by M supply chain manager; production planning of each supply chain Business Unit is done by collaborative planning. This internal collaborative planning is elaborated thanks to meetings and by exchange between M supply Chain Manager and each business unit supply chain managers.
- logistic processes in Business Unit are modelled with SCOR processes (Source, make, deliver) and specified with ARIS (figure 7).

Thanks to a modelling study which was done in collaboration with Business Unit costing managers and supply chain managers, cost drivers are determined for each supply chain process in each business unit. Table 4 details for each family process the associated cost driver, and the budgetary responsable. Note that this study is done for each level of granularity.

Business Unit	Process	Associated Cost driver	Process Responsable
BU1	Source	Supplier Number	BU 1 Supply Chain Manager
	Make	Production setup	BU 1 Supply Chain Manager
	Storage/Deliver	Delivered product quantity	M Supply Chain Manager
BU2	Source	Product type number	M Supply Chain Manager
	Make	Production setup	BU 2 Supply Chain Manager
	Deliver	Delivered product quantity	BU2 Supply Chain Manager
BU3	Source	Product type number	M Supply Chain Manager
	Make	Production setup	BU 3 Supply Chain Manager
	Deliver	Delivered product quantity	BU 3 Supply Chain Manager
BU4	Source	Product type number	M Supply Chain Manager
	Make	Production setup	BU 4 Supply Chain Manager
	Deliver	Delivered product quantity	BU 4 Supply Chain Manager
BU5	Source/Storage	Product type number	M Supply Chain Manager
	Make	Production setup	BU5 Supply Chain Manager
	Deliver	Delivered product quantity	BU5 Supply Chain Manager
BU6	Source /Storage	Product type number	M Supply Chain Manager
	Make	Production setup	BU6 Supply Chain Manager
	Storage/Deliver	Sold product quantity	M Supply Chain Manager
M Supply Chain	Plan DRP	Product type number	M supply Chain manager
	Plan Production Planning	Production setup	M supply Chain manager

Table 4. Cost Drivers and logistic processes in Supply Chain Business Unit

The major objective of this study is to compare two supply chain management strategies in order to elaborate a good collaborative supply chain planning:

- first strategy is called Pull strategy and consists in managing supply chain with a pull approach.
- second strategy is called Financial Pull strategy and consists in integrating financial constraint in product selection during supply chain planning elaboration.

The horizon level is 12 months, and the planning horizon level is the week. In order to compare these two supply chain strategies, ABS concept is implemented. Next paragraph presents the specificity of the action models (computers models) built for this case study, and last paragraph presents scorecards and metrics obtained thanks to the proposed approach.

4.2 ABS instance on M company supply chain

Considering the complexity of the case study, discrete event simulation was preferred to mathematical models for many reasons such as modelling constraints and computation time. Hence, simulation is used to reproduce supply chain working during 12 months. The specification of supply chain running thanks to ARIS modelling is translated in discrete event simulation computer model (figure 6).

Both plans were obtained from two dedicated heuristics which are integrated in the simulation model. Indeed, the difference between both planning results from the choice of manufactured products after each end of production lot on each factory. Production Plans given by to heuristics and simulations are then evaluated thanks to an instance of the financial analytical model. For each plan, a financial budget is then associated.

Figure 13 presents the ABS which is done for this case study.

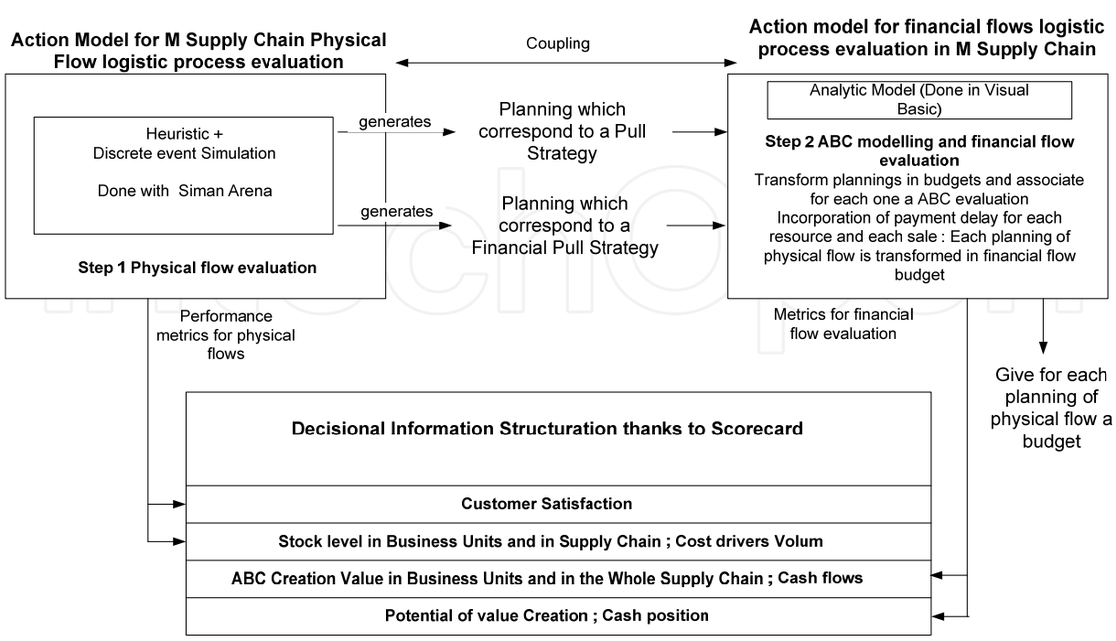

Fig. 6. ABS Structure for M Supply Chain.

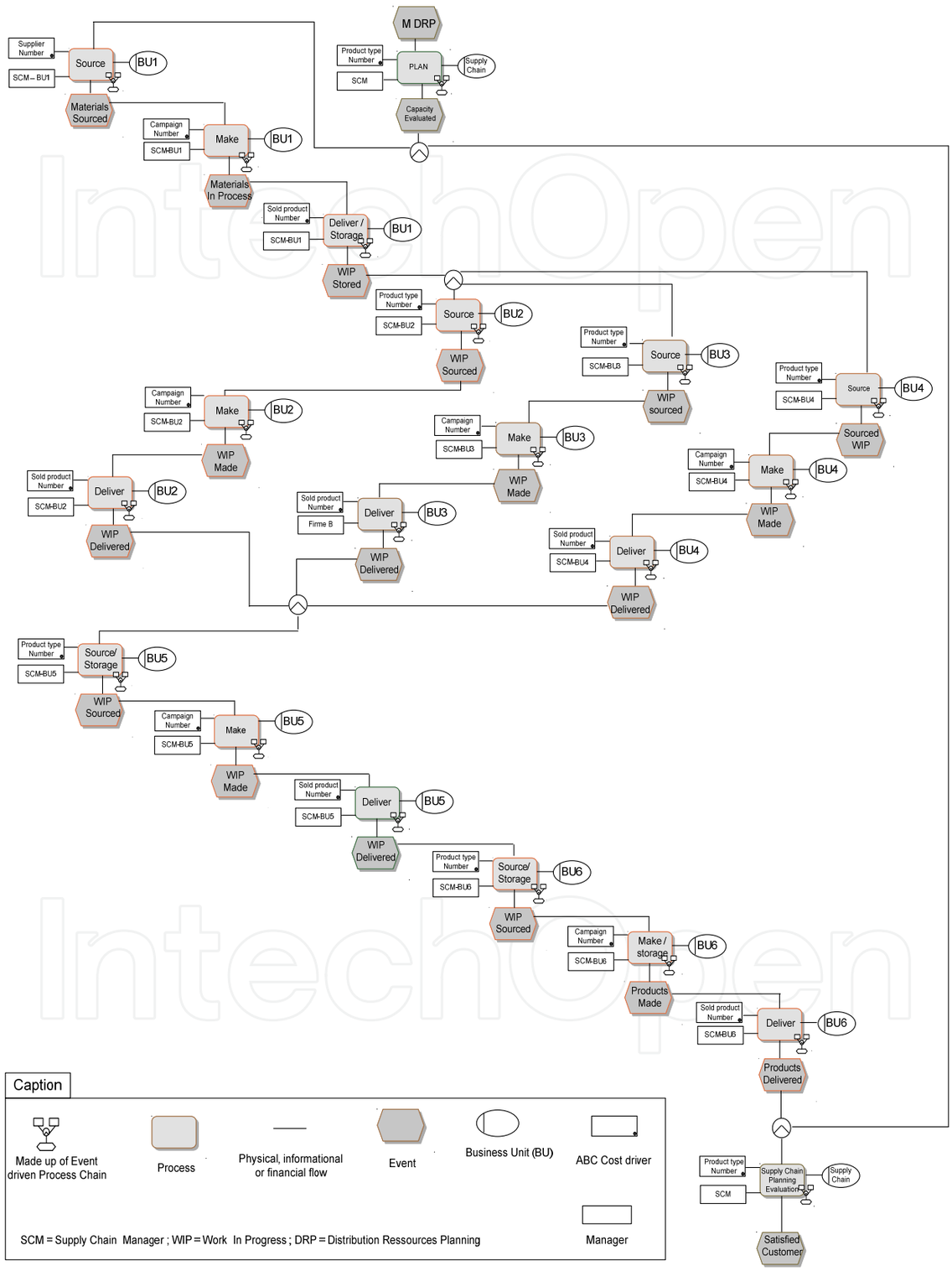

Fig. 7. Supply Chain specification

Both heuristics reproduce Supply Chain Managers behaviours in Business Unit.

The first one reproduces Supply Chain Managers behaviours in Business Units in order to build a planning with a pull strategy. This heuristic is a greedy algorithm which chooses the type of products which gets the least autonomy. The calculation of a parameter called "Autonomy" corresponds to the number of periods where customer demand can be satisfied with the actual stock level of finished products. This heuristic is used as a benchmark to evaluate other strategies of physical flows. This one is called pull strategy. Its description is given in algorithm 1.

```
    Initialization
 ProdType:=0                        // set the product chosen to 0
 AutonMin:=∞                        // assign the autonomy to infinity
    for i:=1 to n do                // for each product i∈I
    Calculate Autonomy(i)           // calculate autonomy of product i
      if Autonomy(i)<AutoMin then   // if autonomy of product i is min
         AutoMin :=Autonomy(i)      // update AutoMin
         ProdType:=i                // assign product chosen to i
      endif
    endfor
```

Algorithm 1. Heuristic for Pull Strategy

The second heuristic is similar to pull strategy but integrates financial constraints. Product selection process integrates financial preferences, and the product family which has the smallest payment term is firstly chosen. This one is called financial pull. Its description is given in algorithm 2.

Regards to these data, these strategies consist in prioritizing in each factory the family of products, which get the least autonomy. State of system is used as input data by two heuristics. Each heuristic takes into account finished products stock levels since these data allow estimating Supply Chain autonomy for each factory (autonomy i). A full strategy is thus reproduced along the Supply Chain.

These heuristics are implemented in a Discrete event Simulation model done with ARENA. Thanks to this action model, physical flow running is reproduced, and plans can be generated. Plans of physical flows gives:

- quantity of made product in each BU and in the whole Supply Chain;
- quantity of cost drivers used by each process in each BU and in the whole supply chain;
- quantity of products sold and stored in each BU and by the whole supply chain.

In a second time, these planning are evaluated by a second model. This second model combines information from physical flows planning with data given by supply Chain ERP. This financial computer model is done and linked to Discrete Event Simulation Model with Visual Basic. Both models reproduce financial flows running under supply chains management strategies and give physical and financial metrics.

```
Initialization
ProdType:=0                          // set the product chosen to 0
FinanType:=0                         // set the product payment term
                                     // chosen to 0
AutonMin:=∞                          // assign the autonomy to
                                     // infinity
   for i:=1 to n do                  // for each product i∈I
   Calculate Autonomy(i)             // calculate autonomy of
                                     // product i
    if  Autonomy(i)<AutoMin then     // if autonomy of product i is
                                     // min
      AutoMin :=Autonomy(i)          // update AutoMin
      ProdType:=i                    // assign product chosen to i
      FinanType:=PayTerm(i)          // assign product payment term
                                     // of the product i
    Endif
   endfor

   for j:=1 to n do                  // for each product i∈I
   Calculate Autonomy(j)             // calculate autonomy of
                                     // product i
    if  Autonomy(j)=AutoMin          // find another product with
      and ProdTerm(j)< FinanType then // the same autonomy and a
                                     // better product payment term
      FinanType:=PayTerm(i)          // assign product payment term
                                     // of the product i
      ProdType:=j                    // assign product chosen to i
    Endif
   Endfor
```

Algorithm 2. Heuristic for Financial Pull Strategy

4.3 ABS scorecards

The results for physical flows evaluation by the proposed approach after 12 periods of 1 month are given in table 5 and 6. As mentioned above the chosen model for this step is the simulation one. This model was developed with Arena 7.0 and the simulation run takes 3 minutes on a PC with 1.8 GHz processor and 256 Mo of RAM. The global model (which links physical and financial flows) takes ten minutes after 12 periods of 1 months.

The results presented above are given for the whole horizon time. Note that it is possible to detail them for each period. Results show that the closing stock level is better (in quantity) in strategy pull than in strategy financial pull. However, it is quite difficult for supply chain manager to choose the strategy since the demand satisfaction level is nearly the same as well as the number of production setups. Therefore, an evaluation of cash flow level and ABC level thanks to the ABS will help supply chain manager to have more information and by this way to take the right decision.

a) Physical flow evaluation in Financial Pull Strategy (on the whole period)

Products	P1	P2	P3	P4	P5	P6	Global SC
Quantity manufactured *1000	565	521	470	316	212	192	2276
Customer satisfaction	100	100	50	50	100	100	83
Number of production setups	26	21	25	19	17	17	125

b) Physical flow evaluation in Pull Strategy (on the whole planning period)

Products	P1	P2	P3	P4	P5	P6	Global SC
Quantity manufactured *1000	577	532	570	578	13	16	2286
Customer satisfaction	100	100	80	100	40	40	83
Number of production setups	26	21	25	19	17	17	125

Table 5. Physical flow evaluation

	Products in Financial Pull							Products in Pull						
Business Unit	P1	P2	P3	P4	P5	P6	Total	P1	P2	P3	P4	P5	P6	Total
BU1	1200	10000	9700	10000	800	800	32500	0	1600	0	1600	21000	18600	42800
BU2	No storage in BU2													
BU3	No storage in BU3													
BU4	No storage in BU4													
BU5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BU6	5600	19900	5480	4900	3100	2900	41880	2000	17200	3580	2200	1300	600	26880
Global	6800	29900	15180	14900	3900	3700	74380	2000	18800	3580	3800	22300	19200	69680

Table 6. Stocks level (in quantity) in Business Unit at the end of the planning horizon

Same income statements are created for each business unit and for the global supply chain. The computations use the analytic model developed in section 2. All results are given in Euros. Note that Budgets could be given for each product in each business unit for each period.

It is very interesting to evaluate (as shown in section 3) the value creation (figure 8), cash flow level and cash position (figure 9), potential of value creation (table 7). Value creation evaluation gives manager the possibility to know which products create value and where (in which business unit) value is created and where value is destroyed because of planning. To conclude this section, table 8 gives final results and planning selection.

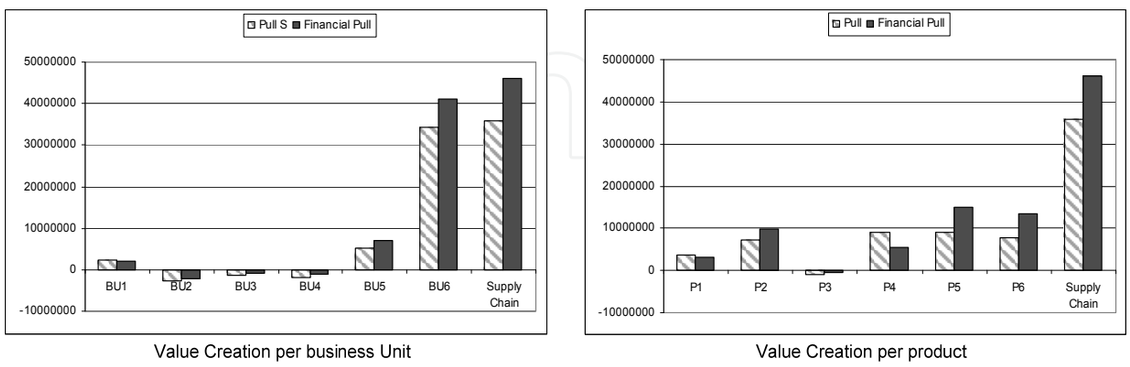

Fig. 8. Value Creation

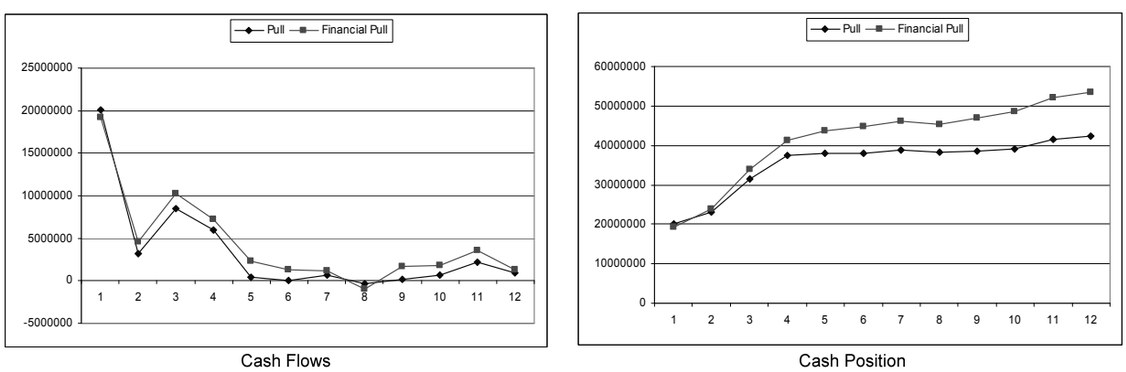

Fig. 9. Physical flow impact on financial flow: cash position and cash flow generated by different planning

In figure 8 and 9, note that the graph is very similar in period 1, 2, 3. The impact of planning strategy on financial flow is observable only three months after its beginning because of payment term, which is three months for main products P1 and P2 in this industrial case study.

	P1	P2	P3	P4	P5	P6	Global SC
Potential of Value Creation in Financial Pull	0	0	0	3859751	0	0	3859751
Potential of Value Creation in Pull	0	0	0	0	10347757	9740813	20088570

Table 7. Potential of value creation in strategy Financial Pull and in strategy Pull

	Financial Pull Strategy	Pull Strategy
Customer satisfaction	≈	≈
Stock level in quantity	-≈	+≈
Classical physical flows metrics gives very few differences: its very difficult for Supply Chain manager to select planning		
Value Creation	+	-
Cash flow	+	-
Cash position	+	-
; Potential of value Creation	+	-
Planning selection	**+**	
Thanks to ABS software, Supply Chain Manager is able to select planning with physical and financials parameters		

Table 8. Final result evaluation and planning selection

5. Conclusion

This paper proposes a global software concept for flows evaluation (physical and financials) in company supply chain. This software, called ABS for Advanced Budgeting System gives the possibility to associate planning and budgeting processes in Company Supply Chain. In case study, the financial model is coupled with simulation model. This choice, explained in section 4.2 will allow integrating stochastic phenomenon (such as demand variability, uncertain breakdown …) in order to study strategies robustness. Nevertheless, the proposed approach is generic and leaves the possibility to be used with mathematic models implemented in classical APS software. This approach was tested in an internal supply chain (a multinational company) and gives the possibility to select plans thanks to it. Of course, it improves the visibility of cost but the most important point in this approach is to show how physical flow impact is passed down to financial flow by taking into account payment terms. The proposed approach gives managers the possibility to select planning thanks to:

i. physical metrics (given by physical flows computers models);
ii. financial metrics (given by the generic financial flow model). This approach completes actual approach in operational, tactical and strategic planning selection.. This approach was only tested in tactical level. Since the approach is generic for logistic process in Supply Chain, it would be interesting to test it on other decisional levels such as operational or strategic level. Moreover, this approach, tested for logistic process evaluation in company supply chain could be used in others domains (services, health care systems…): it would be relevant to test it in such domains to see if the approach is enough generic or need to be adapted or re-conceived.

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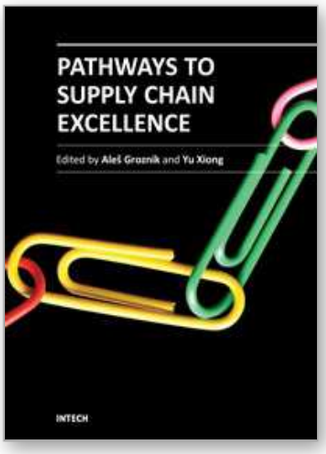

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Over the last decade, supply chain management has advanced from the warehouse and logistics to strategic management. Integrating theory and practices of supply chain management, this book incorporates hands-on literature on selected topics of Value Creation, Supply Chain Management Optimization and Mass-Customization. These topics represent key building blocks in management decisions and highlight the increasing importance of the supply chains supporting the global economy. The coverage focuses on how to build a competitive supply chain using viable management strategies, operational models, and information technology. It includes a core presentation on supply chain management, collaborative planning, advanced planning and budgeting system, risk management and new initiatives such as incorporating anthropometry into design of products.

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