General Use of the Routing Concept for Supply Chain Modeling Purposes: The Case of OCP S.A.

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Abstract. This paper proposes a modelling and formalizing approach to field-work-collected data in order to develop a set of tools to both direct and increase industrial production. The OCP ("Cherifian Office of Phosphate") provided authentic data for the construction and use of an inductive approach. This approach enabled us not only to give details about the problems encountered but also to have the necessary level of granularity required for a number of ex ante management decisions. Several instances of the suggested modelling applications are given in the real context of the OCP's supply chain reengineering. They equally allow the reader to obtain a feedback on the implementation of a twofold modelling generated by a unique collection of knowledge.

1 Introduction

The purpose of this paper is to analyze the solutions to the methodological problems that arose in the first phase of our research aiming to create a dual decision-making support system (DMS) dedicated to Supply Chain management and management control system. This phase has to do with gathering and formalizing the required knowledge to design simulation models on which to base the DMSs. Supply Chain (SC) generally refers to the logistics chain of multinationals. The different subsidiaries of these companies participate in the SC, both from within the organization, and as « satellites » involving multiple third party providers of logistics services and sub-contractors whose operations are coordinated by the multinational company [1]. The SC object of our study is that of Cherifian Office of Phosphates (OCP S.A.), owned by the kingdom of Morocco[1]. Both the DMSs rely on complementary models of the SC, used to simulate its activities dynamically. In this context, management is focusing i) on the tactical decisions to negotiate the terms of new agreements (limited number of customers) and so maximize the margin generated by the SC and ii) on the operational decisions to fulfill its obligations

[1] It is made up of a complete industrial sector (described in figure 5) from ore extraction (more than half of world reserves belong to OCP S.A.), to production of phosphoric acid and fertilizers. The Jorf site located at the end of this SC is characterized by its production plants, owned by OCP as well as by a number of technically similar plants, jointly managed by OCP and its foreign partners under joint ventures (JV). Moreover, the adjunction of 300 km of pipeline (for minerals transfer) will entirely change the SC to enable implementation of production to orders.

under the current agreements while keeping costs down. This paper focuses mainly on the operational management aspect. Highlighting the consequences in terms of time and space of the contemplated operational decisions is largely achieved through the simulation tool, which of course does not preclude recourse to complementary approaches (optimization…) to identify the best course of action. Ex ante assessment of the decisions should be complemented by an ex post assessment by management control, through a tailored management accounting scheme to make a proper economic analysis of the decisions. In the context of production to orders, the management control referential cannot be efficient if it only refers to legacy data. Indeed, the use of simulation techniques is needed in order to obtain a truly relevant referential, one that is built dynamically. We start by delimiting the context of this work (§ 2), and then consider (§ 3) the key concept of routing in order to present (§ 3) some principles of collecting and using the gathered data that we will illustrate (§ 4) with applications in the OCP context before making any conclusion.

2 Research context

Any modeling / simulation (M / S) research on production systems is determined by the objectives sought and by the general characteristics of the system. We shall therefore begin (§2.1) with a description of the objectives of the research as they determine the choice of relevant information to be gathered and the level at which the model is to be designed. (§2.2) analyses the information gathering approaches proposed in extent literature showing their limits for the purposes of this research.

2.1 Objectives of the "dual" modeling

The Figure 1 summarizes our chosen approach. The combined gathering of field information by SC management experts and management control / management accounting players should make for two consistent and complementary representations of the SC's activities. The basic inputs are technical documents used in the field, complemented by observation, particularly of decision-making practices, where the required information is not set out in writing. Such basic inputs (which are not available in the public domain (and therefore not listed in the bibliography)) are processed in order to design a dual model of SC activities, with an adequate granularity for the DMS to be designed. The desired model is intended for use by a discrete event simulator, which is a relevant technical solution for our purpose. The primary data gathering process and its processing in order to build the foundations of a simulation model poses a number of difficult methodological problems.

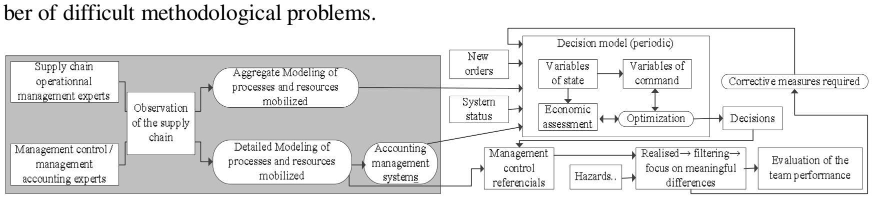


Fig. 1 Complementarity and use of Operational Management & Management Control Models

The M / S created for the operational DMS does not call for a fine detail of SC process mapping; on the other hand, it presupposes a good understanding of the main levers available to decision-makers and a proper modeling of the domino effect of consequences of these decisions in time and space. The first step, therefore, consists in an accurate plotting of the concerned physical activities. In order to further inform the decision-making process, beyond the anticipation of consequences of alternative decisions, one needs to measure their economic impact. This implies recourse to a management accounting scheme based on the second M / S. The M /

S created for the Management Control DMS stems from a detailed mapping of the productive entities of the SC, using a rather local focus. This should enable a better assessment of cost factors and therefore the design of a relevant management accounting scheme, for use both for decision-making purposes to assess the economic aspects and for subsequent control purposes. The economic assessment aspect is not the focus of this paper which will only implicitly refer to costs drivers. It is to be used at a later stage in the operational management DMS to fine tune operational decisions and for tactical decision-making purposes. Moreover, the fact of being able to produce to order should drive the development of a dynamic referential for use by the Management Control DMS.

2.2 BPM, Supply Chain Costing and Supply Chain Management

In 1980's and '90s, a number of technical and managerial innovations took place simultaneously, along with sweeping economic environment changes that led to root and branch changes in the organization and management of Western businesses. These gradually shifted the traditional approach to functional line management and process reengineering" [3], activity costing, project management [4), management software packages were all managerial and technological breakthroughs stemming from a process approach of organization and the associated software. Accordingly, there was a perceived need to systematically draw up models for almost every aspect of the organization so as to identify the good practices and to organize the acquisition of information concerning the organizational processes. A number of authors and actors have defined [5] the Business Process Management (BPM) as one which enables the modeling of the business process. Using collected information about the activities of a complex system such as a SC [6], a representation of the organizational processes is designed in the form of a knowledge model (KM) of this system. The KM is defined as the translation in natural or graphic language of the structure of the system's activities. A number of authors [7] suggest a definition of the system process' KM as the aggregation of information and data used to plot interactions, collaborations and associations between system entities in a workflow form. Concretely, the BPM is made up of three phases [5]; [8]; [9]. The first phase has to do with acquisition and validation of the knowledge concerning the organizational process; this phase, whose steps will be described below, is common to knowledge management. The second phase is about formalizing knowledge (using concepts, tools and methods) which is presented as a Business Process Model(our paper deals mainly with this phase).The third phase is that of analysis and of use of the formal models developed in the previous phase [10]. During the analytical phase, corporate actors analyze, use and expand the KM. Four steps have been identified for knowledge acquisition through partial analysis of extent literature: (*i*) the first phase is about the choice of knowledge acquisition mode; the choice of method is bound up with the system and with available information. Moreover, a number of approaches may be used simultaneously; (*ii*) the second phase is about translating the knowledge acquired in the form of rough basic documentation in digital format ; it is key [9] to store the information in digital format so as to improve productivity and traceability; (*iii*) the third phase serves to validate the rough translation of the collected information; (*iv*)the fourth phase concerns the development of basic documentary knowledge to enable the subsequent formalization of the system's organizational process. Note some authors consider this basic documentary knowledge, often presented in natural language, as a model in itself of the corporate processes [11]. Using an iterative approach, basic process knowledge is then expanded as the process is started all over again from phase 1 [12]. Research [12] on corporate use of structured and formalized basic process knowledge highlighted the five following applications (figure 2): (*i*) the knowledge model is used to design the Information System (data storage, basic data, ERP), [11]; (*ii*) the knowledge model is used to design decision-making applications (Advanced Planning and Scheduling, optimization models, simulation models) [13] ; (*iii*) the knowledge model is used to design the performance assessment system (Management Control systems as part of SC Costing), [14,15]; (*iv*) the knowledge model is used to design and validate the current or future corporate organizational process through interaction with target system players [3]; (*v*) the knowledge model is used for organizational process certification purposes under the quality management approach.

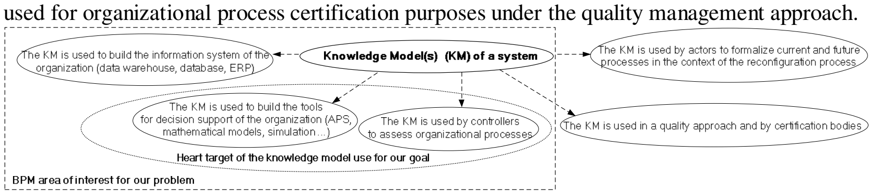


Fig. 2 Multiple uses of knowledge model systems.

Research by [14] showed that a given model may be used by different users; one may suppose that the productivity of the formalization process would be greater if it were centralized and performed once and for all, since the knowledge model draws on the same basic knowledge regardless of use. Indeed, this single process mapping performed as part of the modeling exercise of a complex system may be used, for our purposes, indifferently to design the information system, the decision-making rules and the process valuation/optimization system [7]. In light of SC complexity, introducing a BPM approach serves to formalize the logistical process between and within the systems making up the SC [12] and serves as a pre-requisite for operational collaboration in the long run. As shown in figure 2, BPM activity, which consists in formalizing process system knowledge, also involves producing a documented model useful for different purposes. Nevertheless, in light of our objectives of design of SC Management decision-making support applications, we will focus on use of the knowledge model geared to the routing concept of an SC, and to the creation of a DMS integrating economic metrics.

3 Knowledge use: routing based modeling of SC processes

The gathering of the technical information yields multiple items of different forms and formats, from which one has to extract the relevant information for modeling/simulation purposes. Methodological considerations lead to a detailed analysis of the notion of routing (§3.1) and to to generate the relevant information from the detailed information gathered (provided one relies on properly defined aggregation rules (see §3.2)). One must also achieve the relevant level of detail by keeping the number of objects created in the model down to a minimum (§3.3).

3.1 Routing Components and routing breakdown

Routing is central to technical information. Generally speaking, production routing is defined by use of one or several products matching the required characteristics, combined in predetermined quantities, to obtain, after a certain time (processing time), with the help of multiple material (equipment, machinery…) and human resources (operators), all being viewed as components of a processor, the desired product (or products in the case of linked productions). Figure 3 shows the components of a Routing and their « combination ». To every reference i of an input is associated a bill of materials coefficient q_i; symmetrically, to every reference j of an output is associated the quantity q_j produced by the operations. These quantitative data (q_i and q_j) are structurally consistent.

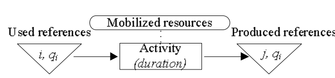


Fig. 3. Representation of a Routing

The above general definition helps to breakdown production operations into the different elementary steps, each characterized by an elementary routing. This is referred to as a detailed routing. These elementary steps are connected by logical relationships of precedence (a downstream step may not start until the upstream step has been completed), in which a product made upon completion of an elementary upstream step is used by the next elementary step downstream. These different routings are generated to satisfy different needs (real time order, ordering, scheduling). Detailed routings may be viewed as a description of the production process. Detailed routings gathered in the field generally do not match the required level of detail for a dual modeling/simulation of the SC under review. They, however, enable one to generate the relevant information from the detailed information gathered, provided one relies on properly defined aggregation rules (see §3.2). One must also achieve, in the required model, the relevant level of detail by keeping the number of objects created in the model down to a minimum (§3.3).

3.2 Aggregation Rules

Aggregated activities encompass all of the elementary steps of the detailed routing, together with the products exchanged between these elementary steps. Four rules are relevant to the elementary routing aggregation:
(i) The rule of legacy as to time sequence: The time sequence relationship linking the different elementary steps that are merged into an aggregated activity will disappear, as does any trace of the products exchanged between these elementary steps. The aggregated activity inherits the time sequence relationship linking an elementary step to another lying upstream or downstream, but that are not included in the aggregated activity (figure 4).

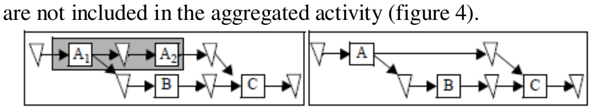


Fig 4. Rule of time sequence relationship legacy

(ii) The rules of consolidation duration: The above analogy with project management helps define the duration of aggregated activity as equal to the duration of the critical path calculated on the flowchart of the detailed routing, where cycles are not noted. This duration consolidation rule is subject to the following three constraints:

(1) In discrete production, the processor which performs an activity handles a single batch (or unit) at a time and only processes the next one once the first has been completed. A transposition of this principle to aggregated activity distorts the representation of reality, since the processor performing the first elementary activity of the aggregated activity is in a position to handle a new batch as soon as it has finished the previous batch, without having to wait for the batch it has processed to leave the processor performing the last elementary activity of the aggregated activity.

(**2**) adaptation to line production is straightforward if one considers that the line production process can be approximated by a discrete process handling small batches (for example, a batch corresponding to product volume manufactured in k minutes by the processor, k being the number of minutes).

(**3**) The duration of aggregated activity is only valid provided there is no interruption in supplies, preventing an elementary activity on the critical path from being performed

(iii) The rules of resource consolidation: The resources mobilized by every elementary activity are all mobilized by the aggregated activity. Application of this principle in project management poses a problem as it is obvious that the mobilization of a non-storable resource by an aggregated activity does not imply its use throughout the activity. In the context of modeling/simulation of a production process, this objection should be dropped if the proposal described above to allow the process to handle simultaneously n batches is adopted as, at any time, all the non-storable resources are simultaneously consumed by the n batches.

(iv) The flow conservation rules: The aggregation method should respect the principle of flow conservation: at cruising speed, what enters the plant (expressed in weight or otherwise…) is necessarily equal to what goes out, knowing that some output may be waste.

3.3 Definition of the granularity level

The risk of modeling is that of adopting too fine a level of detail. Two principles should guide this effort: define a model that is relevant for the decisions to be taken (*i*) and limit the number of model components to a minimum (*ii*).
(i) Modeling relevant for the decisions to be taken: The level of detail of each of the two M / S should be consistent with the objective of the DMS using it and enable the exchange of relevant information between the two DMSs. Note the issue of a possible decoupling between certain SC sub-systems which serves to circumscribe in time and space the scope of analysis of the consequences of certain decisions. The economic aspect will be looked at subsequently with reference to the management accounting scheme, which is linked to the second DMS. Its aim is to globally minimize overall costs. The tactical management goal of the first DMS is to maximize the margin generated by the new orders, through a contribution to the negotiation process, and, in particular through provisional production capacity, possibly subject to availability of certain raw materials. This corresponds to a wider scope and different missions which may call for the mustering of other approaches, such as mathematical scheduling, to complement the simulation approach. The level of M / S detail for management control purposes is clearly different than that geared to operational management. The complementarity of the two DMSs implies that the basic production unit used for modeling is not shared by other units of the model on which the operational management DMS is based.
(ii) Limitation of the number of components consumed in the modeling: To facilitate comprehension and maintenance, the proposed model should be as dense as possible (for a required level of detail). The M/S applications enable the design of components from basic components (processors, inventory…), which may be used as new basic components to be reused to build new components. M/S applications also enable use of parameterized routings that may be used in a particular productive sub-system to describe its use by different types of production. Finally, these enable pinpointing a single processor to describe multiple identical processors working side by side. These different possibilities shall be leveraged, taking into account the different aggregation rules proposed.

4 Examples of application of these principles in the formalization of the gathered data

We present below the application of the principles developed in our research with examples of information gathering and processing. Figure 5 describes the configuration of OCP S.A.'s SC and offers a representation of the information gathered, processed and formalized. The primary information is made up of textual descriptions of the process and its resources, but excludes part of the implicit routing information. A flowchart with a list of additional required information is obtained. The system processes three types of flow; a zoom is proposed on one of these. The granularity level presented here is for information purposes.

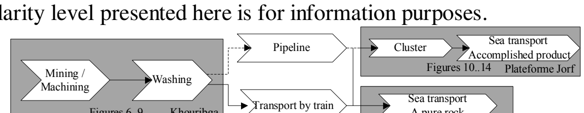
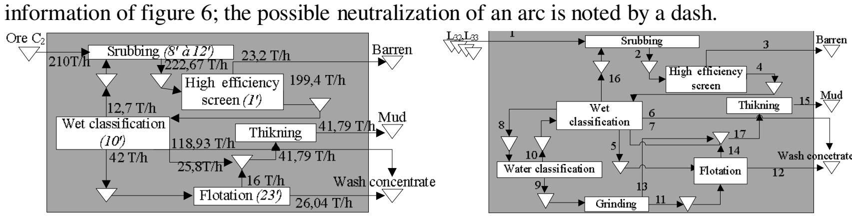


Fig 5. Macro modeling of OCP S.A.'s Supply chain

The process documentation of an ore washing chain (text, tables, maps) supplied was quite exhaustive and we noted that the washing site comprises six identical washing chains. The documentation highlighted differences related to the type of ore transformed, in terms of system and resources used as well as flow path. The first phase of translation of this data was the creation of a detailed routing for each type of ore input, with the output ("wash concentrate", as it is called) being always the same. Figure 6 represents one of the 4 detailed routings. It features rate and average processing time. The principle of flow conservation is respected. The average processing time is approximately of 26.1; the fact that the process is a cycle complicates the calculation somewhat (the result was obtained by simulation). Figure 7 illustrates the aggregated routing derived from the detailed routing. It should be highlighted that this information is valid in cruising speed and that this is also true for the following examples. A juxtaposition of the 4 detailed routings yields figure 6, which shows a parameterized routing model. The numbered arcs of table 1 serve to identify the rate information (for example, line C_2 corresponds to information of figure 6; the possible neutralization of an arc is noted by a dash.



Exhaustive detailed routing *Parameterized routing*

Fig 6. Exhaustive and parameterized routing - C_2 ore washing

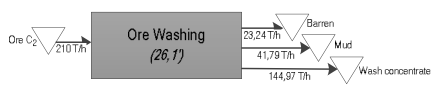


Fig 7. Example of exhaustive aggregated routing - C_2 ore washing

Intrant \ N°Flux	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
C_2	300	318	33	285	60	170	37					37		23	60	18	60
C_{31}, C_{32}, C_{33}	300	335	30	305	73	77	60	137	60	77	42	71	18	44	122	35	122

Table 1 : Rates (tons/hour) of the parameterized routing of figure 6.

Super components may be designed through recursive construction, thus appearing as a specific category of components. On the Jorf platform, OCP S.A. owns three workshops organized as a flow shop (figure 8). The phosphoric acid and fertilizers production workshops are each represented by a component obtained through the same creation process as that used to build the sulfuric workshop component. The sulfuric and phosphoric acid productions are shown as external inventory as they may be used indifferently by the OCP S.A.'s workshops and those of Jorf's Joint Venture. The super-component is represented synthetically as in figure 9. Jorf's JVs are characterized by production units that are derived from OCP S.A.'s. They may be "grafted" onto the sulfuric acid supply, (which they do not produce) or onto the phosphoric acid supply, in which case, they only manufacture fertilizers, or onto both. The Jorf platform, therefore, is made up of the OCP S.A. production plant onto which the JV's production plants are grafted.

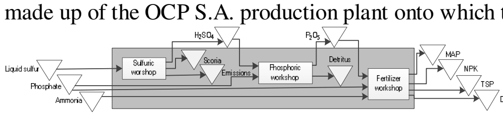


Fig 8. Example of recursive modeling

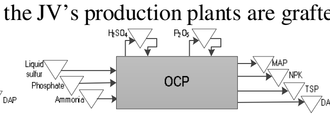


Fig 9. Example of super-component

This plug and play type configuration leads to the model described in figure 10, where the Indian JV (IMACID) (producing phosphoric acid), the Brazilian JV (BUNGE) (producing phosphoric acid and fertilizers) and a JV project under study are integrated, thus illustrating the modularity of the approach. In terms of modeling, it suffices to parameterize the OCP S.A.

component to be able to describe the Jorf industrial complex with an adequate level of granularity for management purposes.

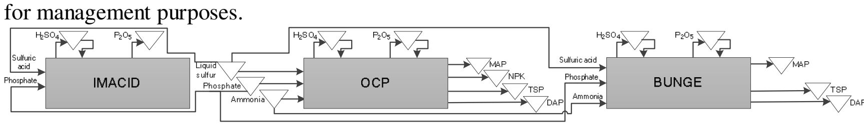


Fig 10. *Plug and play* configuration

5 Conclusion

This paper proposes a routing-based modeling approach to a complex logistics process. This approach forms part of a BPM but goes beyond it as the knowledge gathered may be used in different ways (both for management control and operational management purposes through a combination of the physical flows, see fig 2). It therefore stands out as an innovative approach with multiple scientific and management implications. Though its relevance is clearly limited to SCs of the type under review (where DMS may be modeled on activities that are interconnected and where a single totally integrated organization exercises control), our proposed approach appears promising for a wide variety of applications: coupled modeling of “operational levels” should yield decision-making applications including physical and financial aspects; construction of a single referential to measure logistics performance of operations throughout the production process; the construction of real time **activity valuation scheme** feed into industrial management control referential. In short, there are multiple prospects for implementation of our model.

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