AN MRP-BASED ARCHITECTURE TO PLAN RESOURCES AND TO MANAGE WAITING QUEUE IN HOSPITAL SYSTEMS

Raffaele Iannone, Claudia Pepe and Stefano Riemma
Department of Mechanical Engineering, University of Salerno, via Ponte don Melillo 1, 84084, Fisicano (SA), Italy

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Abstract: In the last decades, the interest in the development of healthcare planning and control systems is quickly spreading. Hospitals quality improvement, in fact, is actually a continuous process mainly aiming at improving the professional services rendered to patients, not only in terms of effectiveness of cures but also in terms of efficiency of supplying services system. For a long time, researchers have discussed about how the benefits in terms of reduction of waiting times and waiting queue, obtained by the IT application in manufacturing, can be achieved also in hospital systems without forgetting that healthcare supplies the basic good: health. Resources coordination according to patients who are in hospital, allows the reduction of "slacks" at resources due to discharge delays, late-start surgeries and slow laboratories turnaround. Therefore a resources planning system has been implemented in order to reduce the high waiting times and increase resources utilization in hospitals. The paper describes the methodology to create a dependent demand starting from patients needs and proposes the implementation of an MRP (Material Requirements Planning) procedure for hospitals. The PDTs (Diagnostic Terapeutic Path) for each patient in hospital are generated. All the PDTs are used to calculate resources, materials and facilities requirement in short-mid term, after having linked resources to the services that hospitals are equipped to provide (BORM – Bill of Resources and Materials). In this way the MRP procedure is able to plan resources, facilities, materials and HR in accordance with the real "demand of patients" and highlight potential overloads and problems.

1 INTRODUCTION

The dynamism of hospital systems represents a penalty for healthcare organization and management. More and more, in last decades, these structures have been considered like enterprises and the complexity of their problems has increased the necessity to provide hospitals with information technologies in order to make easier to collect, archive and manage data. A relevant example is the introduction of electronic patient case sheet whose aim is to collect and store clinic data about patients and their case history (Grimson J., Grimson W., Hasselbring, 2000).

Besides data recording and management, one of the biggest problem hospitals have to face with is the wide waiting time, due to the increasing of demand, as well as poor coordination of available resources. At the moment, for example, in healthcare organizations it is not possible to know, in advance, the utilization of resources and their availability. Often, the time necessary to provide services to patients is estimated by doctors and physicians only according to their experience. Moreover, like any manufacturing firm, hospitals are organized in departments and wards which are specialized in supplying particular services. Most of these work units are formally independent, have their own resources and work with autonomy. Nevertheless, some departments and wards are transversal towards other departments. That means they need to face with departments to whose they supply services. The resources of transversal departments are critical so their management and coordination by monitoring their utilization can bring benefits in terms of time and costs.

For this reason, hospitals need a planning and control system to plan patient admissions and required capacity in order to optimize services supplying times and the utilization of resources. This matter has always been object of scientific researches directed to hospitals performances improving. In the past, researchers considered the possibility to use an MRP system, based on dependent demand, to solve planning problems in

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healthcare systems by developing a new system, named HRP - Hospital Resources Planning - (Roth and Van Dierdonck, 1995). After them, other authors presented a hierarchical planning framework for production planning and control in healthcare organizations (Vissers, Bertrand, and de Vries, 2001). Their research confirmed that MRP logics can be applied to services environments besides industries differently from Shahani who said that hospitals correspond to complex stochastic systems so the common deterministic approach for planning and managing is inadequate (Shahani, 1991).

MRP has been used almost universally in manufacturing firms and has proven to be a valuable technique for reducing inventory investment and improving production planning, getting "the right materials to the right place at the right time" (Chase, Aquilano Jacobs, 1998). Then, ERP and MRPII systems allow production activities planning and material needs definition by considering resources availability in order to satisfy the production plan based on forecasting and orders. It means that systems, knowing orders and forecasting elaborate data about stock inventories, lead-times, BOMs of products, production cycles, resources capacity and managerial strategies to define the working plan and the allocation of resources to the jobs, optimizing times and reducing costs (Chase, Aquilano Jacobs, 1998).

This paper deals with the development of a prototype for managing and planning hospital resources. The idea is to implement an *ad hoc* system for healthcare organizations based on ERP/MRPII functionality, born and developed in manufacturing environments. The system is able to plan activities, in mid-short time, according to needs of patients who are in hospitals and those who are waiting for their entry.

2 THE MODEL

Hospitals are service companies whose aim is to supply an important good, health, by coordinating and managing a large quantity of resources. They, often, are characterized by high waiting times and costs which can be due to a bad management of resources. In order to apply to hospitals the logics used in manufacturing, and try to obtain the same advantages, it has been necessary to analyze and schematize the dynamics of services supplying in healthcare structure.

The design of a planning process for healthcare organizations firstly requires knowledge about processes.

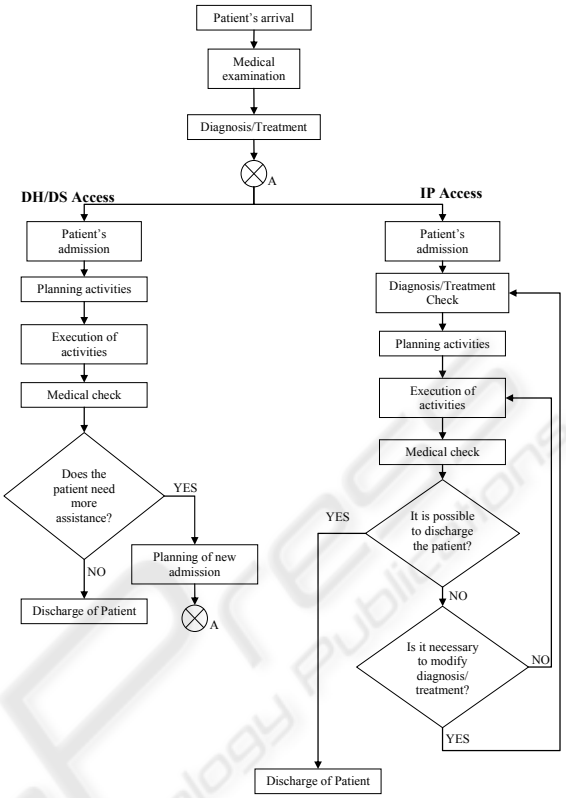

Figure 1: Flowchart of hospital processes.

Figure 1 shows the flowchart of an hospital patient after being admitted. First of all the patient receives a medical examination to evaluate his health and define the treatment he needs. After that, according to the state of his health, the typology of access in hospital is defined. During their stay in hospital patients are often examined by physicians who decide whether patients have to be discharged, or the treatment has to be changed or new diagnostic examinations are required. The patients path ends with their discharges from hospital. Figure 1 also points out that patients are the most important actors inside hospitals and all the decisions are taken according to their diagnosis and their reactions to treatments.

During his stay in hospital each patient needs specific resources, materials and facilities that are shared with all other admitted patients. Most of time hospital administration is not able to check the real availability of resources because the resources utilization according to the admitted patients' needs can not be a priori known.

Table 1: General-Paths' phases of PDT types.

	IP PDT type	DS PDT type	DH PDT type
Phase 1	Outpatient Check	Outpatient Check	Outpatient Check
Phase 2	Diagnostic Tests	Diagnostic Tests	Diagnostic Tests
Phase 3	Pre-Surgery Evaluation	Surgery	Follow-up
Phase 4	Surgery	Stay in Hospital	Discharge
Phase 5	Stay in Hospital	Follow-up	
Phase 6	Follow-up	Discharge	
Phase 7	Discharge		

To apply the MRP logic to hospitals we have to look at the patient as the "customer" of the healthcare structure and the required services (diagnostic examination, treatment, specialist consultation) as the "products" hospitals have to realize (Iannone, Pepe, Riemma, 2007). In this way patients can be linked to services and services to resources.

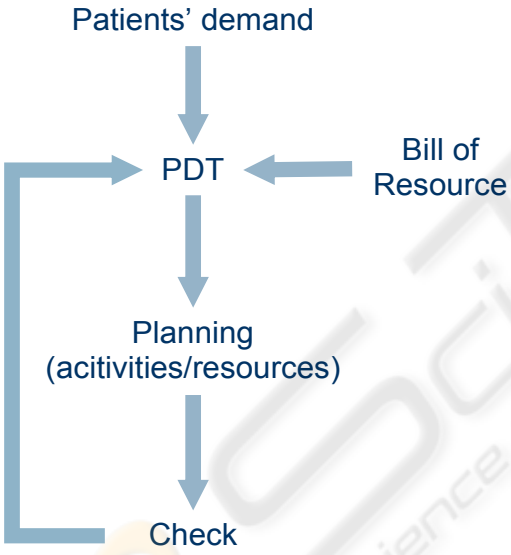

Figure 2: Flowchart about logic of system

The totality of patients needs represents the demand the hospital has to satisfy in a time as short as possible, and according to whom it has to organize available resources. After having defined the demand and therefore the net requirement to supply, a link between each patient requirement and the related materials and resources has to be defined in order to fulfil a suitable activities and resources planning,. For this reason, a Diagnostic-Therapeutic Path (PDT) has been associated to each patient. It contains all the information about the patient and his "medical" path inside the hospital where he is requiring services. By PDT it is possible to know all the activities that have to be realized in order to guarantee the service supply. For each activity the time, materials and resources necessary to complete the service are specified through the "Bill of Resources and Materials" (BORM). PDT is dynamic because physicians can change the treatment process and when a change occurs resources are re-planned in real time according to the new necessities (Figure 2).

2.1 Patient's access and PDTs

First of all, hospitals organize patients' access: the Emergency Department for emergencies case; the Outpatient Department for patients who need Day-Surgery; the diagnostic centres for diagnostic Day-Hospital and Inpatient Wards for admitting patients that require overnight treatments.

In this project two main group of patients' access typologies have been considered: OutPatient and InPatient.

OutPatients are patients who do not need to occupy bed-resources or who need them maximum for one night/day. The choice of supplying services in one day, when it is possible, is more widespread and often physicians decide to operate on patients in Day Surgery. Two access typologies are defined for this type of patient:

- Day Hospital (DH): the patient stays in hospital just for the time necessary to do NOT INVASIVE medical examinations, tests or treatments and then he is able to go back to home without requiring any bed (blood transfusion, chemotherapy, moisturizing, etc.)
- Day Surgery (DS): the patient is admitted in hospital and requires a bed just for one day. It is possible to do surgical operation, INVASIVE diagnostic or therapeutic activities that need partial or total anaesthesia (ophthalmological surgery, gastroenterology, gynaecology, otolaryngologist, orthopaedic, etc.).

InPatient, instead, is the typology of patient who needs to stay in hospital more than one day and night. In this case the access typology is just one:

- InPatient (IP)

The PDT (Diagnostic-Therapeutic Path) is defined as "complete route patient follows inside healthcare structure to solve patient's health problem" (Università L. Bocconi . CeRGAS, 2001). That means it describes the sequence of activities necessary to supply the suitable aid to the patient when symptom and diagnosis are known.

PDT is characterized by a *General Path* that highlights the main operational tasks linked to the typology of patient's access (Table 1) and a *Specific Path* which represents all the activities that the patient has to follow to obtain the service he asks for.

The General Path of a PDT is associated to the patient according to his access to the hospital. On the contrary, the activities of the Specific Path are defined, time to time, by physicians or qualified persons.

The described schematization has been used to facilitate the inserting of patients data on the electronic planning system. When a patient goes to hospital he is registered on the data system. In fact, it is not possible to start the planning procedure if patients data and requests are not inserted in the planning software.

Patients data are put in a sheet, called PATIENT SHEET, that allows the storage of all the necessary patients data and the unequivocal identification of the customer inside the system. Moreover, it records all data about previous stays in hospital of all the patients.

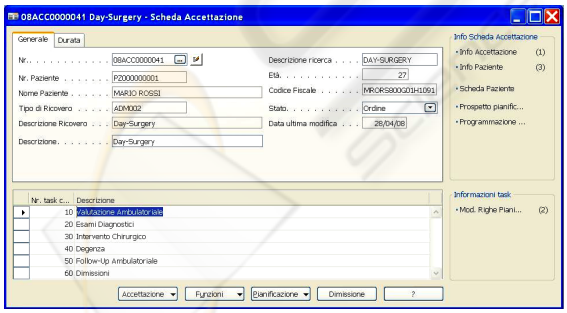

Figure 3: Admission Sheet

If a patient has already been in the healthcare structure, the related Patient Sheet is not recreated but it represents the first step for the planning process: starting from it, in fact, the ADMISSION SHEET (it is linked to the particular typology of patient access), which contains all the information about admission and stay in hospital, is opened.

In the lower part of the sheet, the General Path phases can be imported according to the specific patients access typology. Afterwards they can be modified by specifying the Specific Path activities. The Admission Sheet is active and can be modified during the whole period the patient is in hospital; that means it allows the registration of the whole path the patient follows from his access to his discharge..

2.2 PDTs and Resources

PDTs are characterized, as we already said, by two parts, *General Path* and *Specific Path*, that differ from one another in their levels of detail. The Specific Path contains the list of the elementary activities and services (RX to leg, blood test, electrocardiogram) that the patient needs according to physicians or qualified persons.

Therefore, these elementary activities are linked to the "Bill of Resources and Materials" that specifies the resources, time and materials necessary to realize a specific activity or service provided by the hospital.

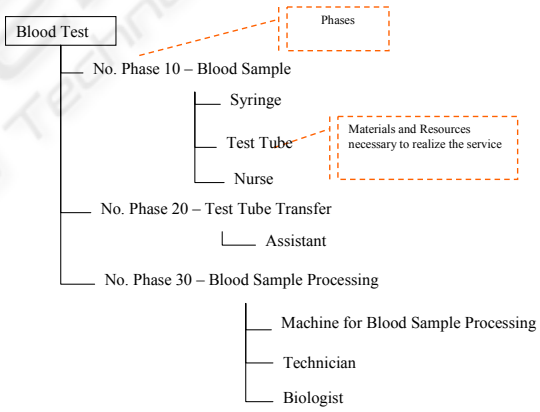

Figure 4: Example of BOR for Blood Test activity.

The explosion of BORM for each activity/service of a specific path of the phases of a general path of all patients PDTs allows the availability of necessary human resources, facilities and materials to be known.

The physician or the qualified person, through the ADMISSION SHEET, is able to specify the required service or the suitable drug-treatment for each phase of the General Path (the lower part of window).

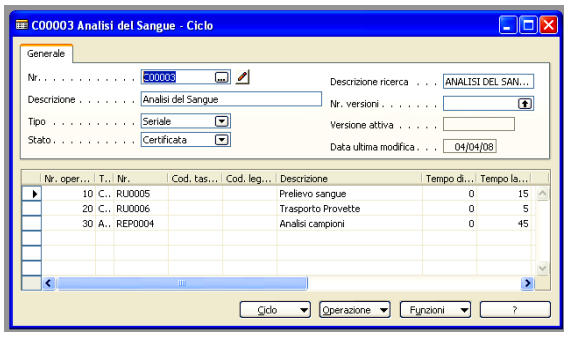

Figure 5: Example of BOR on software system.

Each service, material or drug is registered and archived on the electronic system using a form, called "Item Sheet. In detail, when the form is related to services, it contains information about BOMs (necessary material for supplying services) and cycles (necessary time and resources to do activities); if the form is related to support materials or drugs the Item Sheet contains information about stocks of support material and drug. In this way, it is possible to obtain information about inventory and generate purchasing orders when it is necessary.

2.3 The Planning Process

Services supplied by healthcare organizations (surgeries, diagnostic tests, etc.) represent "products" to realize that, as showed, can be linked to their relative necessary time, materials and resources. They are defined in the electronic system through the ITEM SHEET which contains all the information necessary for their realization.

Resources, grouped in Human Resources, Facilities and Materials (Iannone, Pepe, Riemma, 2007), are defined in the electronic system as work stations that are allocated to departments and influence their total capacity and availability.

The activities linked to the new PDTs, the unpdated PDTs, the capacity and availability of resources are input data for the system. These collected data are suitably elaborated by the system that plans activities and resources according to patients needs.

After having collected information about the required activities, the system is able to produce a list of the planned activities through the calculation of the date at which each activity could be realized based on the resources availability evaluation (Figure 6).

The generated list is confirmed by the planner together with the physician in charge or the department chief who has to realize the activities. When

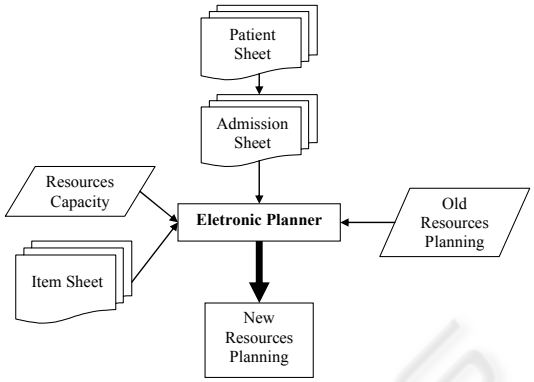

Figure 6: Information flowchart.

the activity starts, the person who realizes the activity or supplies service changes its state from "confirmed" to "released". An activity is "released" when the required resources are really occupied. After having completed an activity, its state is declared "closed" and the occupied resources are released becoming "available".

When the patient is discharged from hospital all the activities linked to his Admission Sheet become closed and resources are available again, even if they (activities) are not completed.

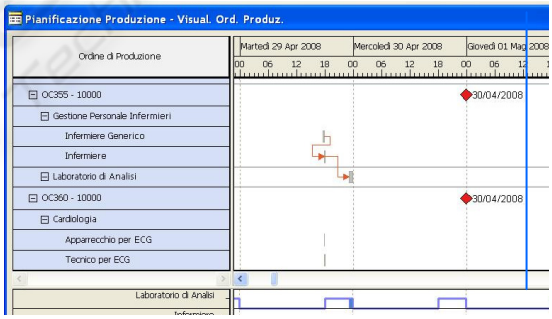

Figure 7: Gantt of resources and activities.

Beside the list of planned resources, another output created by the system is the Gantt chart of the planned activities and resources utilization (Figure 7). The physician or the person who should confirm the planning plan, can change it directly on the chart, by shifting activities that he thinks are bad planned. Once a change on the chart occurs, the system is automatically able to replan all the activities which can be shifted. Moreover, through the reading of the Gantt diagram, it is possible to know the workload of the single resource as well as the specific patient who uses each resource.

3 CONCLUSIONS

The output of the described system is the activities Gantt chart which represents a calendar of the activities that have to be realized inside hospitals according to patients demand.

The proposed logic allows a more suitable management of the resources capacity and availability and, consequently, the improvement of waiting queues management by basing the activities planning and the resources scheduling on requirements. In fact, after building a Gantt's chart of the monitored resources, their availability (facilities, personnel, laboratories, etc.) can be known in real time or even in advance,. When resources are overloaded and it is not possible to realize one or more of the planned activities, patients can be rescheduled in order to meet the available capacity. At the same way, when an emergency occurs it is possible to reschedule not-emergency patients exactly when the resources they need are available. In this manner, the eventuality that a patient is admitted in advance and uselessly occupies resources (beds or food service) in waiting for services that cannot be supplied in that moment is avoided. The update of the system, moreover, allows the real time check of resources overloads or delays in supplying services for patient who are already in the hospital.

The described system can be seen as the first step toward the development of a network able to manage more hospitals and able to sort out patients in healthcare structures according to the required services and the real availability of resources.

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