A proposal of a management framework to optimize waiting queue in healthcare organizations

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Abstract: The internal dynamics of a hospital represent a complex non-linear structure. To plan and manage day-to-day running of a hospital requires a thorough understanding of the system together with detailed information for decision-making. The main objective of a hospital is to offer services of good quality to their patients utilizing their medical expertise with the support of their specialized and expensive infrastructures: personnel, intensive care units, surgical operations units, specialized laboratories besides beds for in-patient stay, ambulances for emergency transfers, pharmacy for the required medicines and the other logistic infrastructures like restaurant for preparing food and the laundry service. To maintain high quality standards these resources have to be coordinated in order to eliminate “slack” at various resources centres and the inefficiencies caused by discharge delays, late-start surgeries and slow laboratory turnaround. For this reason we can say that hospitals need a planning and control system to plan patients’ processes and required capacity. Poor capacity, resources utilization and the more and more high waiting times are among the strategic issues that continue to plague hospital planners. The question is ‘how do we give patients the right services at the right times?’ The following paper presents a tool to manage, plan and coordinate the resources in a hospital in order to reduce the waiting queue and increase the resources utilization. The study applies the integration concepts of ERP systems, widely used in manufacturing environments, to the healthcare organizations. Referring to DRG (Diagnostic-Related Group) and considering the hospital resources linked to the patient treatment (medical staff, nurse, surgery theatres, support departments, etc), a planning and control system is developed. It looks at the patient like the customer who needs the services offered by hospitals and at the treatment like the instrument to define the necessary resources and materials besides the lead times to provide the suitable service. Following the ERP system logic, it processes data (patients and available resources) and planes the resources utilizations according to the real patients needs, highlighting, if there are, overloads and problems. The system considers also difference between in-patient, out-patient, and emergency and integrates the resources of the different departments.

Keywords: healthcare systems; MRP system; hospital resources planning.

Biographical notes: Raffaele Iannone graduated cum laude in Mechanical Engineering in 2000. After a collaboration with Department of Mechanical Engineering (DIMEC) in 2001 he earned his Phd, in Advanced Manufacturing System Engineering, in 2005 with a dissertation on Supply Network Management. Currently he works at University of Salerno as assistant professor in Operations Management. His research areas of interests include Supply Chain Management, Production Planning, Simulation, Operations Management, ERP and Just-In-Time Systems. He has about fifteen publications in national and international conference proceedings and international journals.
1 Introduction

The main objective of a hospital is to offer services of good quality to their patients utilizing their medical expertises with the support of their specialized and expensive infrastructures: personnel, intensive care units, surgical operations units, specialized laboratories besides beds for in-patient stay, ambulances for emergency transfers, pharmacy for the required medicines and the other logistic infrastructures like restaurant for preparing food and the laundry service. To maintain high quality standards all these resources have to be coordinated in order to eliminate “slack” at various resources centres and the inefficiencies caused by discharge delays, late-start surgeries and slow laboratories turnaround.

This task, the good management and the coordination of resources in a hospital, has always been object of scientific researches in order to improve the performances of hospital provide to patients with more and more good-quality services and to reduce the waiting time which people have to face in most cases.

Hospitals structure is characterized by a wards subdivision based on provided medical services, central diagnosis units, central services units and general units. This type of organization in the hospital means, many times, an inefficiency in service providing because of waste of resources; often, their utilization is not optimized, there is loss of knowledge, personnel demotivation and customers are not satisfied. All these ineffectiveness cause most of common problems in hospital structures: accumulation of waiting patients, long waiting time, duplication of diagnosis and therapy with held up resources uselessly, lack of inventories, a large quantity of movements among the wards, materials obsolescence and high, but unnecessary, use of resources and medicines. For this reason, hospitals need a planning and control system to plan patient admissions and required capacity.
For a long time, researchers have often been interested in how it is possible to apply in hospitals the successfully concepts used in manufacturing environment, that is less uncertain than healthcare system. They discussed about how the benefits, obtained by the IT application in manufacturing, can be achieved also in hospital systems in terms of reduction of lead-times and waiting queues. The biggest problem is that healthcare environment has to deal with people not with objects. Therefore, it’s important to planning activities with suitable margin to face unexpected events.

The following paper presents a tool to manage, plan and coordinate the resources in a hospital in order to reduce the waiting queue and optimize the resources utilization. It looks at patients like customers who need the services offered by hospital and at treatments like the instrument to define the necessary resources and materials besides the lead times to provide the suitable services. Following the ERP (Enterprise Resources Planning) logic, it processes data (patients and available resources) and plans resources utilizations according to the actual patients needs, highlighting, if there are, overloads and problems. The system considers also the difference between in-patient, out-patient, and emergency and integrates the resources of different wards.

2 Literary review

As mentioned above, hospitals are complex organizations and their management is a difficult task. It has to integrate and coordinate a number of internal and external entities, taking into account the relationship among them. Hospital managers must reach their objectives by meeting the customers’ demand and optimizing their supplying. It is translated into a rational use of resources (human, financial and material resources) and maximization of customers’ satisfaction, who contributes to enterprise durability. Some authors (Hancock and Isken, 1992) show that well designed patient-planning system can contribute to the improvement of hospital services.

A common current practise (Harper, 2002) is to plan and manage hospital capacities through a simple deterministic approach using average patient flow, average needs, average length of stay, average duration of surgical operations but, mathematically speaking, a hospital corresponds to a complex stochastic system so the common deterministic approach for planning and managing is inadequate (Shahani, 1991).

In manufacturing environment, for years, it has utilized tools for production management and planning support. MRP (Material Requirements Planning) systems are, probably, the most famous one because their logic can be applied in every manufacturing contexts. Anyway, it has be careful when it wants apply these tools in problems with more uncertainty, like the healthcare systems. Hospital can be seen like a very complex multi-product company, where products are the services supplied to the patients. For this reason, the management of “hospital products”, characterized by heterogeneity and complexity, is harder than it is in deterministic environments where number and type of products are fixed.

The utilization of ERP systems in health care industry offers several advantages (Siau, 2003). One of the benefit is the integrated database which makes possible a better coordination and, consequently, the reduction of administrative costs. The same system can be used to track inventory, suppling orders and delivery requirements. This means that healthcare organizations can plan and organize better their resources, as well as to have access immediately to inventory status. The ERP systems allow to collect
information in a shared database so it is easier retrieve data and compare them with other information to determine when demand goes over the availability for a specific equipment.

Jenkins and Christenson (Jenkins and Christenson, 2001) say that application of an ERP system, in healthcare environments, can facilitate the adoption of processes (forecasting workload; managing human resources; identifying specific workflows) that manufacturers use to balance workload with corresponding labour and supply requirements, thereby significantly improving delivery of care.

The ERP systems plan demand and capacity, on an aggregate level, for the long-range forecast. On the short-range planning, the aggregated estimates are disaggregated for individual products and capacities. This desegregation is only possible for deterministic processes where all parameters describing the process are known and constant (van Merode, Groothius and Hasman, 2004). It seems that ERP systems couldn’t be applied to healthcare systems, characterized by uncertainty and variability, but, in their studies, Roth and Van Dierdonck (Roth and van Dierdonck, 1995) conclude that the concepts of MRP/ERP can be transferred to hospital systems. They developed a new system, named HRP (Hospital Resources Planning), which considers DRGs (Diagnostic-Related Groups were introduced in the late 1960s as means of classifying patients who exhibited homogeneity in resource consumption (Fetter and Freeman 1986)) as products with a “bill of resource” (BOR) structure. They consider that patients, within each DRG, possess similar resource utilization profiles and they are clinically similar; so DRG classification can be used deriving length of stay, costs, and incurred charges as dependent variables. In their model they define also some independent variables like primary diagnosis, additional diagnosis, describing complications or co-morbidity, both surgical procedures and significant non-surgical procedures employed, and the presence or absence of psychiatric conditions. Sometimes, patients’ age, sex, discharge status, and payer sources were also deployed as independent variables. At the end, they describe the HRP system just like a MRP system defining the different planning level (medium and short range). They concluded saying: “In conclusion, ERP represents a potential breakthrough component in hospital operations strategy. As hospitals are forced to become more cost-effective and as they begin to reengineer their processes to enable more patient focus and systems integration, ERP becomes a new tool for enterprise-wide resource planning and coordination”.

Later some authors (van Merode, Groothius and Hasman, 2004) declare that integrated hospitals need a central planning and control system: “…by planning we understand the decision process that determines what should be done, and by control we understand the process that assures planned result are obtained…” . Moreover they describe the Roth and Van Dierdonck’s HRP as “a step into direction of ERP system for hospital application”, in fact, it is based on the concept of MRP and DRGs. Classification systems, like DRG system, divide the heterogeneous demand for health services into a manageable (limited) set of products provided by the hospital. The use of the DRG as a product allows to coordinate several departments involved in the management of patients; moreover, since DRGs associated with length of stay and with the treatment, it is possible to know an expected timing of resource utilization. In this way the patients with different DRGs can be partitioned in reasonable time spans. The treatment stages include the use of diagnostic tools, drugs, involvement of physicians, nurses, etc., based on time. Each stage corresponds with a major and logically different step in the hospitalization process,
with a different physical location of the patient and a different organizational unit in charge.

Vissers at al (Vissers, Bertrand, and de Vries, 2001) define a planning framework for hospitals consisting of a number of levels. They want to identify the different types of decisions that have to be taken in an organization and order them in way that optimal decision is taken. At the first level they distinguish the diagnostic and the therapeutic phase. The former is characterized by a bigger uncertainty than the latter one. The next level considers all groups of patients; at this level, required resources (shared or not) are managed and controlled. They conclude saying that only when processes are totally deterministic and lead times are not dependent on the resource utilization, ERP is sufficient alone. For planning capacity of non-deterministic processes, ERP systems are not suitable, because they are not able to disaggregate their estimates to individual patient characteristics. In this case, the “information protocol” (a part of DRG) can be used, but only for planning purpose. Then, the “information protocol” works as a kind of BOR. It can also be made available to nurses via knowledge management system.

To reduce cost, be more competitive, and provide better and more personalized customer care, healthcare organizations need to implement new technologies, such as internet applications, enterprise systems and mobile technologies in order to achieve their desired business changes as well.

Although the current use of information systems is minimal, in these last years, there has been a push towards a new role of IT in healthcare organizations. It becomes to be implemented in healthcare systems not only to support administrative perspective but also for clinical purposes.

In 2003 Siau (Siau, 2003) analyzes the importance of IT systems in healthcare to reduce costs, be more competitive and provide better and more personalized customer care. Besides the internet and its networks, also the enterprise systems, like ERP and CRM (Customer Relationship Management), can be used in powerful way in the healthcare environments not only to integrate enterprise data, but also to give important information and forecasting data to improve provided care.

The aim of MRPII/ERP is to obtain the required quantity of necessary materials in time and at the right place. This is achieved by a good coordination and optimization of available resources taking into account the workloads. These systems help to have, in manufacturing, a reduction of inventories and lead-times, a general improvement of customer service, a simplification of scheduling processes. In healthcare systems, the same concepts could be expressed like a reduction of costs, an improvement of services supplied to patients and a reduction of waiting times (lead-times).

Another important benefit of ERP systems applied to healthcare is its integrated database. This means that all the information are collected in one place, reducing administrative costs by eliminating some of the manual processes. Moreover, availability of a shared database allows to retrieve and cross data to determine how it’s possible coordinate available resources at one’s best.

Although, integration success in ERP implementation is questionable (Hopp and Spearman, 1996), ERP systems functionality improved over the last decade incorporating specific industrial solutions. For example, the Hospital Industry Solution, developed by SAP (IS-H), designed to integrate the clinical, financial and administrative functions and to manage, more efficiently, information coming from different departments, provides an incentive for hospitals worldwide to implement SAP’s R/3 ERP software.
In 2006, Stefanou and Revanoglou (Stefanou and Revanoglou, 2006) present an example of process integration using SAP R/3 in healthcare environment. The system consists of various subsystems which communicate exchanging data and real time information. The SAP R/3 modules, involved in this case, are three: material management (used for medical materials and dispensary administration), financial and hospital (specifically designed for hospitals and used for clinical and patient data administration). The objective of implementing SAP R/3 is to integrate all processes and subsystems into a technological platform to discard manual ordering system. This means that personnel has to use computers and consequently the R/3 menus in order to enter each patient’s daily drugs list. The orders influence dynamically the MRP system used to estimate the required quantities of medicines and materials. The basic idea of MRP system is that the quantities of required goods are calculated considering the existing stock, the demand forecasts and safety stock levels. Because of the short time in hospital operations, the MRP system is based on the “order point” (OP) of each drug. When the available stock is under the OP, a new order is created automatically. In that way hospitals obtained a reduction of inventory in both drugs and materials, an increment in productivity and an improvement in quality service.

Analyzing the previous studies and papers, we reached the conclusion that it is hard to implement ERP systems in hospitals because processes are uncertain. The current used systems (i.e.: SAP IS-H) are very useful to support administrative and/or financial processes, as well as management of materials, but they are not able to link, efficiently, the material and resource requirements to the patient therapies. Other proposed systems, like HRP, which support the planning process, use aggregations of data based on DRG system. This classification system, as de Vries and al. said (de Vries, Vissers and de Vries, 2000), is not efficient to control logistics and operations, even if, data aggregation allows to have a better long-range planning. Nevertheless, hospitals need instruments which are able to plan, schedule and manage their activities to face the increasing of demand caused both population’s ageing in industrialized countries and new diagnostic and therapeutic capacities that bring more and more demands. This increase, felt by patients like long waiting queue, needs structures addressed to resources scheduling and planning to be managed efficiently. For all these reasons, in this paper, we describe a model to manage and plan hospital activities that is a support, at the same time, both scheduling and operational activities during short-range planning phase.

3 Schematization of hospital environment

The aim of the hospital is to provide the best possible assistance at the lowest possible cost or within the limits of available finance. The provision of medical care for patients is often described, in economic sense, as the hospital “product”. This product or service is produced by bringing together men, materials and money in a structured environment, with the patient as focal point of their attention.

A medium-size hospital (200/300 beds) is characterized by a multi-level functional structure. The highest level is the managerial one; director and medical staff are responsible for economic/financial management and the coordination of resources that are at the lower levels. All these resources represent the operational side of the hospital that supply services to patients based on their treatments.
The patient, in fact, can be seen like a customer who receives services from hospital system. The therapies, that have to be followed by the patient to complete the treatment, can be seen like a time-phased “bill of required services and materials” (see figure 1). Facilities, human resources and materials are used directly by patients but clinical laboratories carry out their job without the presence of patients.

Patients can be divided in three different groups:

1. **Outpatient (OP)**. Outpatients are the ones who come into hospital to obtain a limited time service. Usually they don’t need admission and receive the performance in one day (Day Hospital).
2. **Inpatient (IP)**. This type of patients needs a bed because the treatment, they have to follow, takes more than one day.
3. **Emergency (EP)**. Emergencies come directly from the first aid. They take priority, to receive cures and services, over the other patient typologies.

OP and IP come into hospital following waiting queues. Typically, OPs are more than IPs, who take higher priority, and wait for long time before they can be admitted to hospital; this, above all, because there is not a good scheduling of resources. IPs, who need admission for more than one day and share resources with OPs, also come into the hospital using waiting queues based on the specific ward they need. EPs, instead, take top priority to use necessary resources, facilities and materials because their critical conditions don’t admit any wait. The admission for this type of patients can not be planned but statistically forecasted.

In order to understand hospital needs it is necessary, for each service-supplying part, to identify elements that must be managed and planned based on patients demand. These elements can be classified in the following groups:

- **Human Resources**
  - Medical staff;
  - Technicians and ancillary staff;
  - Nurses;
  - Reception staff;
- **Facilities**;
Fixtures;
Equipments;
Support;

Materials;
Drugs;
Medical products;
Support materials;

Most important function of structures and personnel, linked to the patient’s cure, are described in the following part.

3.1 Human Resources

Human Resources (HR) in a hospital are responsible for the quality of the service provided to patients with applications of cure, scientific procedures and assistance. All these typologies of resources have to be planned in accordance with patient’s needs.

Medical Staff. Analyzing a hospital structure we would expect to find at the head of the medical organization a Medical Board composed of all the specialists or consultants who are members of a medical staff. The functions of the Medical Board can be summarized as advising the Hospital Board on the creation of policy, overseeing all aspect of medical care and treatment within hospital, ensuring that the medical staff has an organization that is effective in achieving the hospital’s goals, providing for the continuing professional education and development of medical and paramedical staff, cooperating with other hospital and health agencies in providing comprehensive health care for community.

Medical staff in a hospital is grouped in specialized wards; for example there can be general medicine, cardiology, obstetrics, paediatrics etc. These subdivisions are important to have a correct planning of requirements in accordance with planned surgeries. In fact, these groups are not interchangeable so they have to be differentiated and planned into details to provide required services. The availability of these resources is based on work shifts and on the number of available units for each category of medical staff.

Information about the necessary medical staff typology is inside patient therapy and linked to the surgery for the specific treatment (decided by medical staff).

Technicians and ancillary staff. Their activities, complementary to the medical ones, contribute to provision of service offering technical support for specific operations. Some examples of these resources are: dentist assistants, X-Ray technicians, nutritionists, laboratory technicians, etc. Because of their importance to provide some critical services, they have to be planned in accordance with patients demand.

Nurses. Nursing is organized in order to provide assistance and to take care of patients. Each patient-care unit includes some supervisors who manage and direct nurses’ activities. The supervisor has to control supplies and schedule of the staff’s work shifts. The availability of these resources has to be continuously planned basing on wards needs.

Reception Staff. The reception staff is assigned to admit and discharge of patients to or from the hospital. Their job is not only to collect patient’s data (personal particulars and necessary documents) but, also, to inform patients about their rights during their stay inside the structure. This staff is important to guarantee an exact information flow and an improving of services quality.
3.2 Facilities

Facilities ($F_i$) can be classified by the typology and the way of use. Most of them are limited so they have to be planned in order to guarantee suitable use to obtain the efficiency that hospital wants.

**Fixtures.** These facilities are characterized by the necessity to move the patient, who needs that, toward them. Some examples are: operating rooms, CAT and X-Ray rooms, etc. This category can generate further requirements of resources and/or personnel to perform their services.

**Equipments.** They are characterized by the possibility to move themselves toward the place where the patients needs. Some examples are: ECGs, spirometers, audiometers, defibrillators, etc. These category of facilities are more than fixtures facilities because they are cheaper and characterized by more waiting time and delays for waste of them inside the different wards.

**Support Facilities.** Support facilities are connected to the stay of patient but they don’t contribute to the treatments. They can be used by patients for temporary movements or for all the stay, for example: the bed, traction system, etc.

3.3 Materials

In hospital, the management of materials (MA) is a very hard task because they are different in typology, not regular in consumption and because there are a lot of demands of small quantities distributed all over the structure. To solve this management problem, it is possible to classify them in three different categories: drugs, medical products, support materials.

**Drugs.** These materials are characterized by a requirements depending on typology of the treatments. Their management needs a constant check of inventories because the “shelf-life”, sometimes, is really short. Most of time, in hospital systems there is a central dispensary, that stores all type of drugs, where all departments pick up for the daily needs. Their management is critical for patients’ safety, so, it is important to control continuously their typology and condition (i.e.: temperature, humidity, lighting, etc.).

**Medical Products.** Medical products have a shelf life longer than drugs so they don’t need the same attention; but a good management of them, which participate directly on the care procedure, is a way to minimize waiting times and costs.

**Support Materials.** Material support is not involved in the care procedure but it is essential for the stay of patients. Some examples are: sheets, meals, etc.

3.4 Supply Service Units (SSUs)

Services, supplied to patients, take place coordinating all the resources previously described. They, suitably (sometimes dynamically) grouped, provide different type of services. The groups can be, for example: hospital wards, clinical laboratories, diagnostic laboratories, operating rooms, surgeries, centre for dialysis, etc. The following part describes some of these facilities, named “Supply Service Unit” (SSU) (see figure 2), to understand how they are used to provide right performances.
Figure 2 Scheme of the Supply Service Unit (SSU)

Hospital Wards (HW). The Hospital Ward is a set of human resources, facilities and materials that provides specialized care to patients who are admitted in hospital. Each of them needs some quantity and typology of resources based on number of patients inside the structure. It is necessary to plan these resources to optimize process time and avoid useless waiting queues. Patients, who are inside the hospital, are, generally, inpatients who will stay in the structure for a long time. The utilized facilities are, above all, support facilities and equipments to measure vital parameters. Materials include all categories and their requirements can be planned with some days in advance basing on patients who stay in the ward.

Clinical Laboratories (CL). Clinical Laboratories include human resources, facilities and materials to provide service. They don’t need the patient’s presence to give the service. Anyway, their requirements are related to the patient’s therapy. A good planning of the required tests, even if for a short period, would allow these structure to organize resources in order to face demands maximizing the efficiency and avoiding waiting queues.

Diagnostic Laboratories (DL). Diagnostic Laboratories provide services of radiodiagnostics, magnetic resonance, nuclear medicine, echograpy and endoscopy to inpatients, outpatients and emergencies. These laboratories have, generally, very expensive fixtures equipments utilized by doctors and/or technicians in order to give specific diagnosis. Materials, drugs and human resources they need, can be planned based on the list of services they have to provide.

Operating Room (OR). Operating rooms are SSUs that require medical staff, technicians and ancillary staff to work well. Materials, used during surgeries, have to be planned with care in order to have everything is necessary without any mistake. They provide their services to every type of patient guaranteeing the top priority to emergencies. Facilities can be fixtures or equipments even if, most of time, they are specific for each operating room.

First Aid (FA). Activities in a first aid ward require medical staff and nurses who give cure to emergency patients utilizing materials, facilities, equipments and all the supports they need. The execution of these activities is influenced by stochastic events such as the arrival rate of patients and their state of health. When patients arrive to the first aid, during admission phase, they are classified basing on an emergency code. The
list, created following this code, could allow a very short-term scheduling of activities. The planning of this SSU could be done basing on statistical data about arrivals and discharges.

**Surgeries (S).** Surgeries, unlike the previous centres, provide services only to outpatients. The necessary personnel, facilities and materials can be planned ahead because they have a long patients’ waiting list with all the requirements prescribed by the treatments.

Table 1 shows the relations there can be between operational resources and some SSUs previously described.

**Table 1** Relations between SSUs and generic resources

<table>
<thead>
<tr>
<th>Supply Service Unit (SSU)</th>
<th>Category</th>
<th>Resources</th>
<th>HW</th>
<th>CL</th>
<th>DL</th>
<th>OR</th>
<th>FA</th>
<th>S</th>
<th>…</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Human Resources</td>
<td>Medical staff</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
</tr>
<tr>
<td></td>
<td>Human Resources</td>
<td>Technicians and Ancillary staff</td>
<td>X</td>
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<td>Human Resources</td>
<td>Nurses</td>
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<td></td>
<td>Human Resources</td>
<td>Reception staff</td>
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<td></td>
<td>Facilities</td>
<td>Fixtures</td>
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<td></td>
<td>Facilities</td>
<td>Equipments</td>
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<td>Facilities</td>
<td>Support</td>
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<td>Materials</td>
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<td>Materials</td>
<td>Medical products</td>
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<td>Materials</td>
<td>Support materials</td>
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<td>Patients</td>
<td>Outpatients</td>
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<td>Patients</td>
<td>Emergencies</td>
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Each SSU is able to provide a set of services, for this reason the table above, described at macro detail level, has to be further detailed because the “Supply Service Activities” (SSA) (micro detail level), supplied by SSU, have to be linked to necessary operational resources. Pushing toward a deeper level of detail, the SSA would require, for examples, specific drugs, consultant of a particular branch or other SSAs supplied by other SSUs.

Table 2 schematizes an example of this process. It is considered a generic day surgery, whose main phases are listed afterwards:

i. Administrative admission
ii. Pre-surgery tests
iii. Hospital admission
iv. Medical revaluation of tests results
v. Surgery
   a. Movement of the patient to the operating room
   b. Patient training (preparation)
   c. Anaesthetization
   d. Preparation of operation
   e. Operation
   f. Patient’s medication
   g. Cleaning of operating room
vi. Movement of patient to the intensive care room
vii. Keep patient under observation
viii. Movement to the patient’s room
ix. Stay in the bed of the patient
x. Evaluation of patient’s status by medical staff and check of the dischargeability
xi. Discharge

Table 2 shows, for each phase, resources it needs to provide the correct service.

It is evident that some required resources during the surgery phase (clinical laboratories, X-ray laboratories, operating room, bed etc.) are SSUs; that means these have to be further exploded in accordance with the SSAs. In fact, they need personnel, facilities and materials to provide the required services.

This analysis is important to understand how hospital activities, activated by patients’ demand, require necessary resources based on the prescribed treatments. These resources can be shared and limited. Figure 3 shows the data flow starting from the patient, who, in accordance with his treatment, requires services to the SSUs; these, according to the specific SSAs, require operational resources in terms of materials, facilities and human resources. The operational flow, vice versa, follows the opposite direction to achieve, by required services, the patient who activated the process.

![Diagram](image)

**Figure 3** Scheme of data and operations flow activated by patient
### Table 2  Relations between SSAs and specific resources

<table>
<thead>
<tr>
<th>Resources</th>
<th>Details</th>
<th>i</th>
<th>ii</th>
<th>iii</th>
<th>iv</th>
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<th>vi</th>
<th>vii</th>
<th>viii</th>
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<td><strong>Human resources</strong></td>
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Desegregation of treatments, in terms of elementary activities for each patient, allows to reduce uncertainty related to the real use of resources. This result, added to a constant updating of the therapy status, permits to schedule “short-term” activities more accurately and the “mid-term” with lower uncertainty and in a more efficiently way.
4 Proposal of a management methodology

The already proposed approaches, to apply ERP systems in healthcare environments, are still limited to support operational activities without having suitable tools to plan and schedule activities. Actually, the control of information flow, inside complex structures, as a hospital, has brought remarkable improvements on management ability but, anyway, there is still a gap between the support offered by current systems, above all to administrative workloads, and what they could offer in terms of optimization of resources according to the real needs.

Taking into consideration the structure of activities described in the previous paragraph, the proposed architecture wants to plan resources, facilities, materials and human resources in accordance with performances provided to patients. The idea is to implement, inside hospital system, a method to manage flow of information according to pull logic, as it happens in manufacturing companies. This logic, permitting to plan activities and schedule resources based on requirements, improves management of waiting queues checking capacity and availability of resources. Moreover, it could permit to give, in advance, information to the suppliers about real utilization of materials so to wait queues checking capacity and availability of resources. Moreover, it could permit to give, in advance, information to the suppliers about real utilization of materials so to obtain, optimizing processes, a reduction of supplying times and costs. The proposal intends to offer to the hospital manager a complete picture of activities have to be done, in short and mid-term period, and the necessary operational resources.

The scheme of the conceptual model of the proposed management architecture is shown in figure 4. This scheme, taking a cue by the classic production planning model (Hopp, 1996), utilizes information relative to customer’s demand and forecasting of required hospital services to construct the Master Admission Schedule (MAS). MAS is the list of the patients who stay in the structures and those are waiting to be admitted with their admission and discharge dates.

Figure 4 Conceptual model of the proposed architecture
By way of an example, in figure 5 is shown the structure of the MAS. In the first column there are the planned patients related to the main temporal window (month). They are identified by the patient’s typology (IPᵢ, OPᵢ, and EPᵢ) and a code which recognize the prescribed treatment. Patients are grouped based on the ward where they are going to receive cures. Likewise manufacturing production planning, also in the MAS, during the “frozen period” (it is exhibited in red in the figure), it is not possible to modify the planned admission schedule. As described above about particular provided services and customers, when there is an emergency, some planned activities can be moved in order to give priority to urgencies. In the figure is shown an example: the admission of patient OP₂, planned for period 9 at the ward 2, is re-planned for period 13 because it has to give priority to the admission of patient EP₂ at the same ward.

All patients, waiting for admission and whose start date is planned out of the “frozen period”, are those of the “waiting list”. They are put in the MAS and can be re-planned in accordance with urgencies or new management needs. The length of stay, based on diagnosis and therapy, is associated to each patient. Knowing the treatment, it is possible to estimate the utilization of resources the patient needs to receive cures.

Time-phased requirements of materials are exploded basing on MAS, treatments and inventories. This task is quite similar to the classic MRP explosion in manufacturing environments. During this phase, it is possible to check the stock of materials and, if necessary, to plan supplies in order to meet activities of the MAS. Moreover, this step is important to optimize the utilization of resources because, for example, lack of materials can be known in advance and the admissions to the hospital can be re-planned suitably.

The Hospital Capacity Planning (HCP), instead, is necessary to check the availability of resources (facilities, personnel, laboratories, etc.), based on MAS and treatments. If it is impossible to realize some planned activities, the MAS can be modified in order to meet the available capacity. This last step completes the “mid-term planning”.

After developing an achievable MAS, it is released for the “short-term” planning activities, which include scheduling and control. The “activity control phase” allows to have a feedback on use of materials, resources and status of planned activities; all that thanks to patient’s data included in the “case sheet” (i.e.: daily clinical diary, etc.). This control permits, together with possible changes to the treatments made by medical staff, to reschedule short and mid term activities. Moreover, this phase is essential to manage
the uncertainty of hospital environments, related to continuous fluctuation of patients’ status and to dynamicity of their therapies.

To guarantee the correct working of proposed management system, it is necessary to reorganize all SSAs like a process-driven activities. In this way, it is possible to define, for each phase, information about working time (lead-time), facilities, human resources and materials. All phases together (therapy) could be modified day by day in accordance with feedbacks on patient’s conditions (changes can be applied only for unperformed phases, the performed ones will be included in the patient’s case sheet). Next to the phases, typical of the treatment, there are other activities characterizing the stay of the patient in hospital and that require resources for all the period (bed, catering service, etc.).

5 Conclusions

The aim of the described management model is to plan and schedule human resources, materials and facilities inside hospital structure, basing on patient stay and “waiting lists”, in order to minimize waiting time and management costs. These objectives are achieved by a more efficient view of activities to perform, obtained thanks to a process of planning and scheduling management supported by centralized information system.

To know in advance the requirements for each SSU, will allow to respond faster and better to customers’ requests. Anyway, because the model works well, it is essential that the hospital provides itself, like enterprises have already done, with a person who is responsible for “production” planning activities. This figure will have to build the MAS based on real necessity of patients and availability of resources.

As we already said, resources and materials are connected to patients by treatment or therapy, that include the sequence of tests, resources and drugs the patient needs for his pathology. For this reason, the “structure” of treatments and care procedures is an hard task to implement because it has to allow both to integrate all the necessary information and to permit an easy management by medical staff.

Another critical aspect is the dynamicity of therapy, changeable with patients’ tests, because it influences the utilization of resources as well as the length of stay. For this reason, the correct working of the planning process is guarantee only if there is constant updating of information. The patient’s care sheet is essential to have a suitable level of control on the service status and it can be an important feedback to re-schedule the daily activities.

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3-5 October 2007, Pisa, Italy