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A process architecture pattern and its application to designing health services: emergency case

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Abstract

Purpose – The purpose of this paper is to present a process architecture pattern for designing particular components of a complex service. The proposal emphasizes the design of the service production flow component, following modularity ideas, which determines the sequence of actions needed to generate a high quality and efficient service. The authors report its applications to the design of the flow in a single emergency department (ED) case.

Design/methodology/approach – In complex services, production design is usually lacking because production activities are not clearly defined and, in many cases, they are dynamically determined as the service is produced according a client's particular needs. In health services, for example ED, this generates a chaotic production flow that uses resources very inefficiently. The methodology uses a reference architecture, integrating it with disciplines – modularity, analytics and evaluation methods – that provide ideas for formally designing these complex services. This is mainly justified by the fact that, in many such services, no formal design exits and their production processes are the result of practice evolution.

Findings – Methodology was applied to the ED of a large public hospital. The authors first analyzed ED's production and performance data. The authors found two patients' groups that used more than 90 percent of resources. Therefore, design focused on these groups, defining specialized production lines for them and with physical space remodeled by an architecture project, resulting in well-defined separated workflows for each production line. Design also includes coordination with complementary shared services, including specialists consultations' requests and execution, and request, processing and reception of laboratory and radiology examinations. The authors implemented new workflows producing a decrease of 26 percent in patients' delays. More detailed results based on three months of observations also showed, for example, a reduction in examinations waiting times of 80 percent and an increase in the consultation resolution for cardiological patients from 24 to 80 percent in the same day, which means a significant quality increment.

Research limitations/implications – Thus, the authors conclude the plausibility of the idea they proposed that an important design problem in health services, in terms of potential improvements in capacity utilization, is production design. This provides the opportunity to reduce investing large amounts of resources in new hospitals and to instead use the alternative to generate large amounts of capacity by production performance improvements.

Practical implications – The authors are replicating the approach in other hospitals with extensions to inpatient and ambulatory services.

Social implications – Approach produces better service in public hospitals, which is a problem in emergencies in the world.

Originality/value – Formal design approach in health production services is proposed that provides great value by generating capacity, due to better use of resources, that reduces investment needs in new facilities.

Keywords Architecture, Process design, Health services, Production methods

Paper type Research paper

1. Introduction

In designing enterprise's processes in services, architecture patterns have proved valuable, as shown by Barros and Julio (2011) and Knudsen (2017). Also, a recent paper reviews process architecture proposals and shows their relevance for such design (Gonzalez-Lopez and Bustos, 2019). The main idea of these works is to provide a reference architecture that specifies *a priori* what components and with what relationships should exist, to assure an enterprise desired performance. An architecture may be defined, a least, at two aggregation levels: the whole enterprise, as considered in Barros and Julio (2011), Knudsen (2017) and Voss and Hsuan (2009), or at the level of the structure of particular components, as proposed

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by Brax *et al.* (2017) and Patricio *et al.* (2011). In this paper, we present a process architecture proposal useful for designing particular components of a business, which has been tested in many cases that are summarized in what follows. Our proposal emphasizes the services' production flow component, which defines the sequence of actions performed to generate the service. In complex services, such as health, such flows have not been properly designed in many cases (Vähätalo and Kallio, 2014; Broekhuis *et al.*, 2017; Silander *et al.*, 2017). Thus, there is an opportunity to improve them by their explicit and systemic design, which may generate a large impact on quality of service and efficiency. Our proposal, including health production flow design, is applied to the emergency department (ED) of the large and complex San Juan de Dios Hospital in Santiago, Chile.

2. Design approach

Our design approach starts by clearly differentiating production and management processes. This differentiation is obvious in manufacturing, where there is a physical production line and we exert management over its components. In massive simple services, where the products are clearly defined, there are many good production design cases, such as retail –Walmart and Amazon – and digital services – Netflix movies and Apple Music. In complex services, design is usually lacking because of two problems: product and production activities are not clearly defined and, in many cases, they are dynamically determined because the service is produced according a client's particular needs. The extreme case of this type is health services, where defining the sequence of actions performed over each patient depends on the particular evaluation done in each step of the flow. This definition leads in many cases – for example an ED – to a chaotic flow that uses resources very inefficiently. Thus, our objective is to propose a reference architecture that integrates several disciplines to provide ideas to formally design complex services.

There has been a few papers on production design in health services. For example, Porter and Lee (2013) proposed the idea of an integrated practice unit designed for a given clinical condition, e.g. low back pain. This unit uses a well-designed specialized medical flow, which clearly defines what to do for a particular patient's condition. This proposal synthesized the successful experience of several large USA hospitals. Some work has also been done for EDs, including the design of a massive reorganization of patients' flows in a Spanish hospital (Miro *et al.*, 2003) and introducing split flows specialized by type of patients in American (Saghafian *et al.*, 2012; Shen, 2019) and Australian (Ieraci *et al.*, 2008) hospitals. None of these proposals provides a formal approach replicable in other cases. Some related work is the one on fast track streams dedicated to treat minor injuries (Williams, 2006), which are an alternative to the split flows dedicated to the really urgent patients.

We present our reference architecture and the methodology we propose: first reviewing the disciplines integrated in our approach and some evaluation concepts used to justify designs.

2.1 Supporting disciplines

The modern literature on service design emphasizes designing the production of the service itself, contrasting with traditional emphasis on designing the management of the same (Dorbecker and Bohmann, 2013). In health, this means establishing the flow and actions upon the patients, including clinical practices, which are difficult to define *a priori*. Hence, the method proposed here is to design generic flows with variants, differentiated by type of patients, allowing to dynamically determining what to do along the flow. In doing this, protocols are necessary to guide the actions within each stream, possibly, for groups of patients.

We present some of the relevant methods and approaches integrated in the reference architecture and the flow design methodology proposed.

Modularity. One of the methods is modularity, created to design physical products and manufacturing processes, which has been adapted to services (Dorbecker and Bohmann, 2013), concentrating on the design of the physical product-service provided and production processes required. These are related designs because an adequate physical product-service's design may simplify production processes and allow for more flexibility in the offerings. In fact, one of the key ideas is to design physical products-services by assembling components – using predefined interfaces – that are common to many of them. This idea has allowed the designing of complex services, such as the logistics a large European shipping company provides to the fashion, health care and manufacturing industries, using an automated co-creation platform that generates a service customized to users' needs (Pekkarinen and Ulkuniemi, 2008). An interesting related proposal is servitization, as defined by Sheng *et al.* (2012), which covers the problem of extending an existing service to other customers in a dynamic way. For this extension, they propose the formalization of a service using an ontology approach, which is a description of ;all the components of the service and their relationships. The ontology covers what we have defined as the physical service, production processes and organizational descriptions. Then, the ontology can be extended and customized to define particular services for a given client. Sheng *et al.* (2012) give a detailed example for services related to building maintenance, including installed equipment therein, that shows the advantage of designing based on previous knowledge. This is the same idea of the pattern to be presented in the architecture proposal.

In this context, modularity "is the degree to which components of a system can be separated and recombined to create a variety of configurations without losing functionality" (Pekkarinen and Ulkuniemi, 2008). For example, in hospital services the usual design is to have modules for emergency, outpatient and inpatient care services. Then a particular service is dynamically determined for a patient, which define the sequence of actions the different modules perform over him. For example, a patient enters by ED and it sent, once stabilized, to inpatient care, where he will have further treatments until discharge. A case that solved this problem with modularity and an automated platform is a USA metropolitan hospital that was able to integrate outpatient and inpatient care services across the continuum of care (Meyer *et al.*, 2007). Other health cases that use modularity include the services to the elderly (de Blok *et al.*, 2010) and mental health care patients (Soffers *et al.*, 2014) in Holland and a hematology hospital in Finland (Silander *et al.*, 2018). For example, Soffers *et al.* define basic modules common to all services, e.g. living form; others reconfigurable for different segments, e.g. personal care with many variants and alternatives from which to select; and modules customizable at the individual level, e.g. health related care.

Modularity proposals have been validated in health by the results of the cases referenced above, from which the key conclusion is to design components that have a specific function and are relatively independent, minimizing information exchange among them. Thus, interfaces that facilitate recombination, by coordinating and managing interactions among components, should be designed. de Blok *et al.* (2014) have provided a typology for interfaces in health services that includes, for example, sequence constraints and devices that determine the service flow, product books that guide components' selection, protocols to evaluate user needs and determine components and flow, work schedules and service agreements.

Analytics. Analytics was first formalized by Davenport (2006) based on his conceptualization, with some specialization to service design, we define it as the application of quantitative methods to service product and production design, and to its operation and management, distinguishing the following types in order from moderately complex to very complex:

- statistical analysis, such as regression and factorial analysis;
- forecasting and extrapolation, such as time-series models and neural networks;
- predictive models, such as data and web mining models and machine learning; and
- pptimization models, such as discrete linear programming and stochastic models.

These analytical techniques are to be clearly distinguished from the more basic, so-called BI tools, which essentially consist of facilities for access and reporting from data by means of information dashboards. Advanced analytics provides truly intelligence that generates insights on the state of the service and predictive or prescriptive capabilities to support optimal or close-to-optimal actions. For example, Walmart uses online data from all the sales points to feed predictive models that forecast demand for each of such points, which are used by optimization models that determine actions over the supply chain logistics to assure product availability at minimum distribution cost. Currently, they are also using social media big data to predict shoppers' purchases and act on that basis to plan logistics (Davenport *et al.*, 2011; Dezyre, 2019).

In our proposal, we consider analytics of two types:

- data based, oriented to predictive models, which includes traditional statistics and econometrics, data mining, web mining and machine learning; and
- operations research and management science, which make possible prescriptive models, with techniques such as optimization models, both linear and discrete, heuristics, probabilistic models, simulation models, knowledge extraction and characterization models, and many others.

The state of the art in analytics is to use predictive and prescriptive models in routine service production and management processes, which are based and operated on internal and external big data. The aim is not only to drive operational and strategic decisions, but also the design of new products and services. Analytics is performed to advise, recommend and, in some cases, automate decisions and actions using the full range of analytical tools. The example of Walmart we gave before is a good instance of this idea. Other real case example is to use diabetes patients' data, available in the whole health system, to develop predictive models to allow detecting probable crisis for an specific patient, before it occurs, to prevent serious health problems for patients and high emergency treatment costs (Barros, 2017b). Also monitoring and collecting data online for mining trucks, using available sensors, by a service company that sells them and also offers maintenance services, in order to develop models that predict failures just in time, allowing to take corrective actions that minimize the downtime and maintenance costs (Barros, 2017a).

The use of analytics in our design proposal provides a logic that supports the intelligent service production execution and management, and service development using well-founded designs. The central idea is that, in executing services delivery and related processes, logic is necessary to formalize certain routines using models to assure that certain objectives are attained.

Evaluation concepts. In evaluating designs, coordination cost is one of the components of production costs increasing at a rate greater than linear as an organization grows, due to diseconomies of scale generated by management complexity inherent to large size (Malone and Crowston, 1994). An option to manage coordination costs is to split a service into smaller units to make them operate in a relatively independent way, reducing costs in coordinating the production of several different products or services. Hence, this theory supports defining specialized independent production flows, as proposed by modularity before, and Porter and Lee (2013) integrated practice units.

Another evaluation approach is agency theory, where the executive of an organization is the principal and the subordinates are agents (Jensen and Meckling, 1976; Arrow, 1985). This theory proposes that a company is a set of related contracts among individuals with their own interests, instead of the usual assumption that these maximize utility. Therefore, a set of agency contracts allows the principal hiring agents (employees) to perform tasks. Costs depend on the degree of decisions centralization. There are information-processing costs that include the information necessary for the principal to make decisions about the agents' behavior, which increase. Additionally, opportunity costs arise due to the lack of or erroneous information for the decision makers. However, decentralization increases the monitoring cost of agents to assure behavior in accordance with the principal's interest. However this does not assure expected results; thus there is a residual loss. Therefore, the degree of decentralization is a design variable in any complex service.

2.2 Reference architecture

Thus, we propose a design architecture, including the components that are subject to design in a service. This is a synthesis of the experience of many cases in which complex services production processes have been designed, including:

- customized maintenance services for trucks sold by a distributing company and electrical equipment maintenance given by a regional energy generation and distribution firm (Barros, 2017a);
- credit card selling campaigns for banks generated and performed by a firm that process credit card transactions for them and customized e-learning services for high school students preparing their national examinations (Barros, 2017a); and
- at home medical services for children with respiratory diseases, a case summarized below.

The architecture shown in Figure 1, specialized to health, features the production flows defined previously. Over such flows, there are management processes that act on them to obtain a desired performance. Bellow, there are information systems, including the legacy systems, ERP and others, and all traditional IT support to flow execution and management and four intelligent support levels for them. The latter includes variants of analytics, defined

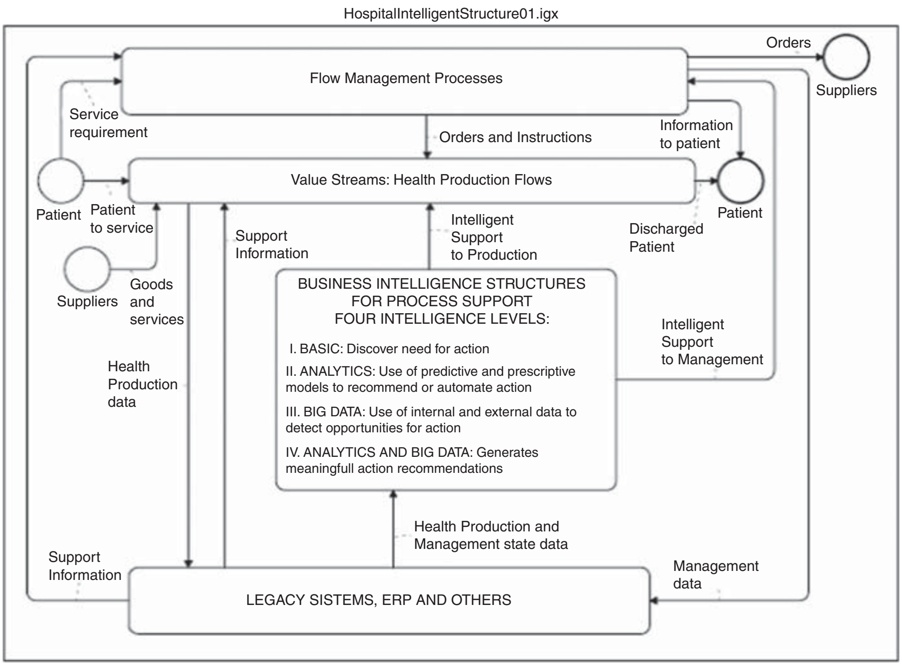

Figure 1.
Architecture for a health service

previously, which exploit information from traditional systems to provide options that may go from alerts and recommendations to the automation of production or management activities. Some implemented real cases of the production's flow support and automation are as follows:

- In the ED of a Chilean children's hospital, the Triage method was automated using a protocol that included a formal logic based on the experience of the best Medical Doctors (MD) of the ED, which provides a classification for patients (Barros, 2017b). This is a case of Level I support, as defined in Figure 1.
- In the ED of a Chilean adult hospital, a neural network model was developed that anticipates congestion and recommends preventive actions, such as assigning more nurses or adding beds (Barros, 2017b); this is a case Level II support.
- Athmapolis (2019) found that approximately 26m people had asthma in 2003 in the USA. For them it developed a technology allowing health care workers to treat asthmatics more effectively by monitoring their treatment on an ongoing basis and collecting data on the environmental conditions when using their inhalers. After three months, 50 percent of these patients could track and manage their asthma condition proactively; this is a case of Level III support.
- A Chilean children's hospital sent chronic patients with respiratory problems to their homes to reduce bed utilization. A design was performed to treat these children using on-line monitoring of medical variables – such as temperature, cardiac frequency and respiratory frequency – and a diagnosis Machine Learning model to determine patients in crisis who need medical attention. This was supported by state of the art computing and telecommunications technologies that make the process effective, successfully implemented at the hospital (Barros, 2017b); this is a case of Level IV support.

Previous architecture allows defining three design problems: the first is the design of the production flows, as defined previously, which is emphasized in this work for reasons previously presented. An example of this is the case of flow's design for the treatment of children with chronic respiratory diseases, using on-line monitoring, for a new service design caring for home-hospitalized children.

The second problem is the management processes design that manages resources associated with the production: doctors, nurses, exams, beds, operation rooms, among others. This design include several levels, such as operation processes, in charge of problems as scheduling of resources; capacity planning processes that determine the level of resources required for a given demand; and new services development. We do not include these designs in our proposal and consider them complementary to production design; this a limitation that indicates the need for further research to integrate design levels.

The third is the information systems design and the intelligent support design. These designs are a complement to and determined by the flow and management design.

2.3 Methodology

The methodology is based on the thesis that production flows in complex services, as conceptualized and defined by the architecture in previous section, should be designed and there is a large potential for benefit generation in doing so. This is mainly justified by the fact that, in many such services, no formal design has ever been done and they are the result of practice evolution. The main service presenting this potential is health, but the methodology has been applied to other services, as exemplified before. The steps for its application are as follows.

First, we perform information analysis to determine which parts of the flow present the best potential for design, searching for groups of clients and services associated with them that use most resources inefficiently. For such groups, we evaluate the possibility of using split flows, with independent specialized lines for them, based on modularity ideas and coordination theory as previously presented. Additionally, we search for situations that most contribute to poor service, for example those that generate more delays. The main idea is to concentrate on the parts of the flow and parts of the flow that may generate most benefits if designed.

Next, we design separated specialized flows when justified by evaluation. Here, modularity plays a key role, since many service flows may use shared modules. In health, Imagen and other exams and specialist consultations are usually common for several production lines; for example, emergency and inpatient. Those modules should have well-designed interfaces that facilitate their efficient use by the lines and for specialized flows within lines. The design also includes the logic necessary to execute the flow in the form of models or protocols that support flow regulation. Here analytics, as presented previously, provides the tools to allow this. The cases presented in the definition of intelligent support levels in our architecture, in the previous section, are good examples of how analytics may be used. Actually, such levels provide a menu of possibilities for any flow design case.

The production flow design, in particularly the logic just discussed, determines the IT support necessary for implementation. For example, analytical databases are necessary to develop and run the predictive models; additionally, applications for routine model running are required, including the possibility of continuous learning as neural models do.

Once design and supporting IT applications are finalized, they should be tested with pilot trials before final implementation. Once these trials show satisfactory results in practice, implementation is performed.

3. Application to emergency design and results

The design approach proposed was adapted to the hospital under study; the work was performed by a team conformed by the hospital ED head, MD and nurses, and academics from the University of Chile, including the project leader and five engineers with graduate degrees in design. The main activities performed are as follows.

3.1 Information analysis

We used full digital clinical records data for July-December 2016 to analyze patients' flow behavior and determine best opportunities for design innovations. The patients in records were classified, using the Triage method ESI, in categories M1 to M5 according to their disease severity, M1 being the most serious. Using the available data, the groups with similar characteristics were established, in terms of pathology type, medical and other resources and problems of delays faced, as detailed below.

The demand, amount of services and box hours were very concentrated in M2 and M3 patients that used 90 percent of the resources, justifying the focus on them.

The next analysis identified the sequence of activities that a patient undergoes and their associated waiting times to identify improvement opportunities. The data allowed calculating the average times associated with successive stages, showing a delay of 6.42 h between first and second medical attention. This delay suggested analyzing the potential cause-effect relationship with exams execution in the laboratory (0.65 h average delay) and imaging (1.46), as well as availability of specialists, performed by components independent from ED. A more refined analysis of diagnostic groups was performed to determine those using more resources and candidates for protocol design to minimize the use of beds before discharge. We concluded that groups with a greater incidence include patients waiting for the execution of examinations and internal consultations(IC) and those with therapeutic limitations, representing 53.19 percent of beds waiting days, reinforcing the need for interfaces to coordinate the relationship with such components.

From these results, we concluded that opportunities for improvement were the waiting times in the conduct and report of examinations, the waiting times for assessment of IC specialists, the times associated with discharges, the need for protocols that support the doctor to speed up the diagnostic confirmation and the time to get a bed in required medical services.

Regarding the most relevant diagnoses, there were three diagnostic groups taking 74 percent of bed's days in the ED: neurology, cardiology and bronchopulmonary. Therefore, protocols to accelerate the diagnosis are justified for these groups.

3.2 Flow design

Due to the previous analysis and after an exhaustive *in situ* observation, we were able to detect the following problems in the flow that make it less efficient:

- attention room locking, due to examinations waiting to confirm the diagnosis, resulted in attention stagnation;
- reevaluation of the patients produced unnecessary delays, increasing the waiting times and patient's dissatisfaction;
- the merging of M2 and M3 patients was produced during the reevaluation process; and
- traceability of patients in the interior of the ED was a constant unresolved issue.

Given these problems, we determined that the design modifications, including facilities' architectural changes, necessary to solve them and obtain a better structure for the patient' care flow were:

- Based on modularity proposals, explained in previous section, independent medical and surgical flows are necessary for patients categorized as M2 and M3, using colored bracelets for each, allowing traceability.
- Independent flows need exclusive areas for patients M2 and M3 with dedicated staff to solve access blocking: waiting room, specialist consultation, patient reevaluation, treatment room, hospitalization box; this requires significant remodeling of facilities, including a station for nurses in each flow, in minimizing the blood sample extraction's time, as well as reducing the time in the laboratory.
- Following modularity, the interactions among the new flows and other service components, such as examinations and IC specialists, requires the design of interfaces, which will take the form of complementary practices in the next section.

The flows design' structure is in Figure 2, shown in the formal notation BPMN for process modeling (White and Miers, 2009), which clearly models specialized independent flows for each group of patients as pools. Interactions among flows in different pools are shown by arrows that follow decisions. Interactions among flows and component services are shown by connectors to and from "Exam Service" and "IC Service," which are implemented with interfaces to be detailed as complementary practices in next section. Main production flows, M2 and M3, are shown as aggregated processes, which are detailed by process decomposition. As an example, we show the detail decomposition of M2 flow in Figure 3.

3.3 Complementary practices

Complementary practices design within the flow provide the interfaces needed, according to previous designs, taking care of the interactions among flows and service components. The design, including IT and intelligent support, is as follows.

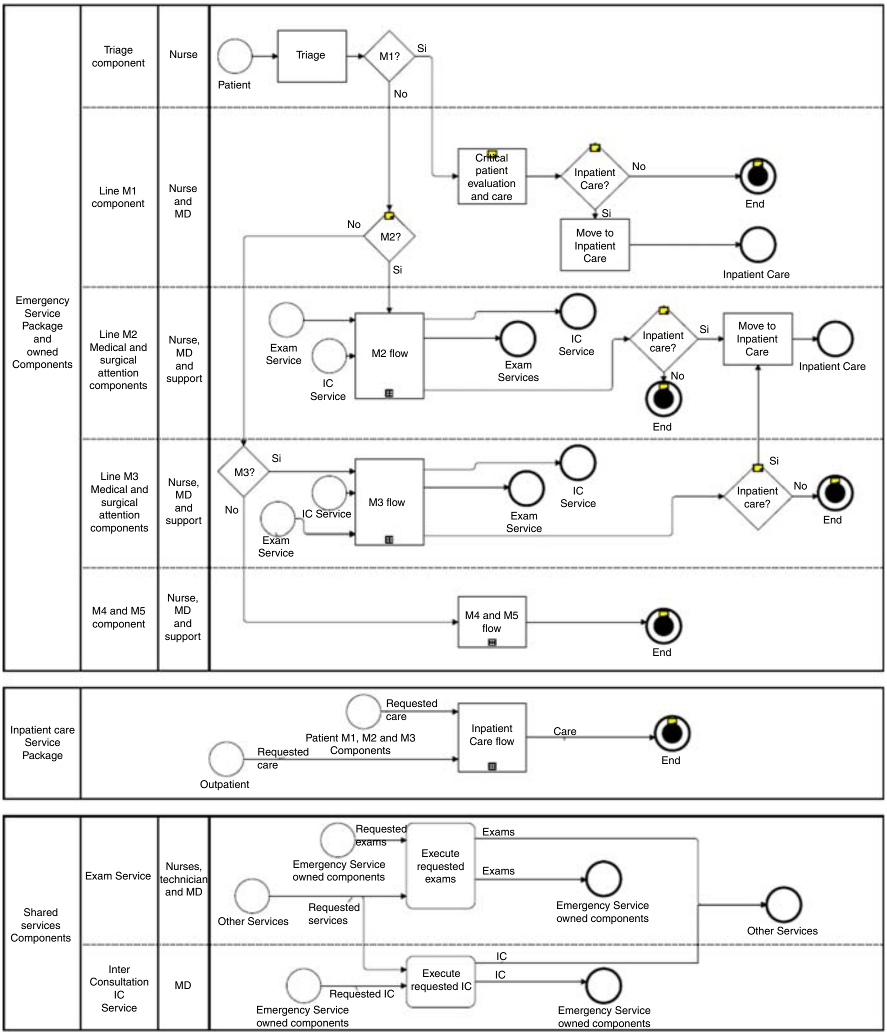

Figure 2.
BPMN for new flows

We proposed a new design for specialist consultations requests and execution, including:

- formalizing the role of an IC Manager to handle request and execution of specialists' work;
- defining capacities for the attention of various IC medical specialties using service agreements properly managed and controlled;
- improving practices for the request and processing of the IC to medical specialties; and
- using collaboration software that supports information flows and process control.

The implementation of this design for cardiology resulted in an increase in the resolution of the consultations from 24 to 80 percent on average during the same day, based on three months of observation, allowing the reduction of cardiologic patient bed days. Given the good results, we started extending this design to all specialties.

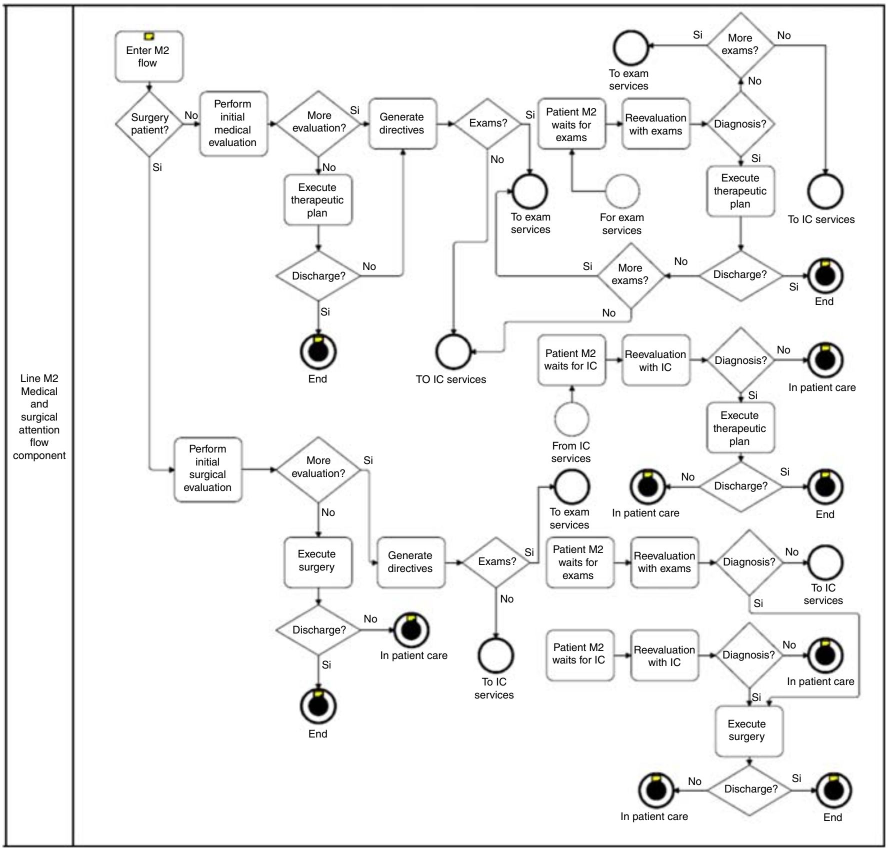

Figure 3.
BPMN decomposition for M2 flow

For the request, processing and reception of laboratory and radiology examinations the design uses a formal interface that ensures medical orders following a single predefined route, with specialized nurses for M2 and M3 patients, improved and standardized laboratory sample wrap, separate pneumatic sample sending devises for M2 and M3, and auxiliary services readily available for transporting radiology patients. The reception practice, as supported by the collaboration software, informs the results of critical examinations. This practice facilitates regular monitoring of the state of patients with examinations requested and alerting nurses and doctors when examinations are available. The results obtained are that the average examination time decreased 30 percent for M2 patients and 80 percent for M3.

Design for consultations and exams are examples of incorporating intelligence of Level I in Figure 1.

Additionally, we developed clinical protocols for specialist consultation for selected pathologies. The protocols emphasize medical workflows that allows solving the problems arising in the gray areas of clinical decision-making. The construction of the protocols consider the following steps, exemplified for cardiology, which we later formalized as a logic diagram:

(1) identification of background variables, such as demographic data and reason of cardiology entry and diagnosis' hypothesis;

(2) identification of tests for the general practitioner, such as ECG and Rx Thorax requested by the general practitioner before evaluation by the cardiologist;

(3) identification of tests for the specialist, such as echocardiogram and Angio CT;

(4) identification of treatment variables, such as clopidogrel and CVC;

(5) criteria for discharge to home, such as normal ECG and echocardiogram normal; and

(6) post discharge actions for emergency cardiac patients, such as control at a cardiology department of an outpatient county facility within three days of discharge and cardiological recipe for 15 days.

The implementation of this protocol has increased almost four times the number of patients' resolutions on the same entry day. Additionally, a decrease was observed in average bed days used by patients from 6.2 to 1.3. This decrease obviously reduces the risk of the patient and increase the efficiency of resource use. This is an example of Level II support with expert formalization using system recommendation. The next planned step is to develop a predictive model using a deep learning neural model to advise the specialist.

Theory justifies this design, because concentrating a group of professionals in a less varied set of activities favors specialization, reducing the complexity of coordination and increasing productivity, as discussed in evaluation concepts. Additionally, agency theory justifies this design as follows. The costs decrease by decentralizing the production execution decisions in the group that runs it, without direct intervention of the hierarchy in the management of the flow. Instead, they have a set of workflow rules, practices and protocols, just defined, that ensure good performance; these are approved by the hospital authorities and interpret the principal's interest.

Modularity is also present in the flows, since they share common service modules among them and with other services, such as for laboratory, imaging and IC, coordinated with well-defined rules and software presented before. In addition, the lines define patients' flow, but there are decisions about the patient that need analytical support; for example first diagnosis provided by intelligent support of Level II of Figure 1 with clinical protocols.

We implemented the new flows during June and July 2017. Comparing the patients' waiting time full data during these periods and following ones, results in Figure 4 that shows the evolution of length of stay (LOS), highest bar being the total average LOS during the observed months. LOS clearly shows a systematic decrease starting July due to the new design, since demand for ED had normal figures for the surge period in Chile. The continuous decrease is due to a learning effect about the new flows and up to September, last month with complete data and comparable demand; there is a 26 percent average LOS reduction, with a continuing decreasing tendency. Additionally, we observed a reduction on transfers from one shift to the next of 58 percent average for M2 and 29.5 percent for M3. Another comparison was made between the surge periods of 2016 and 2017. Figure 5 shows a decrease of almost 50 percent for July and September had a similar reduction with same demand and resources. Direct monetary evaluation of the value generated by the design reveals an ED admissions increase, which was 900 monthly and equivalent to three additional MD during the period. Thus approximately $250.000 annually, including MD and other direct costs, are avoided with respect to previous operation.

4. Conclusions

This paper has advanced on the few intents of using specialized independent health production flows by proposing a systemic design framework that integrates disciplines such as modularity, analytics and economics into a process architecture and associated methodology.

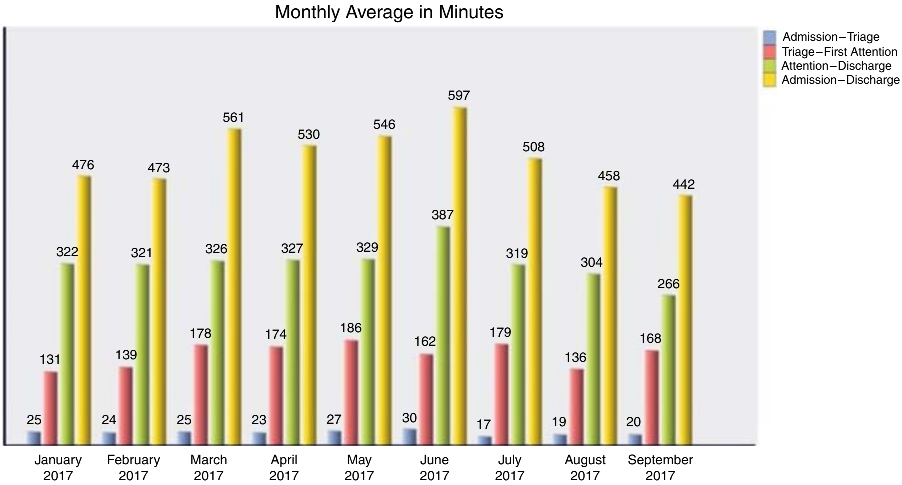

Figure 4.
LOS monthly evolution

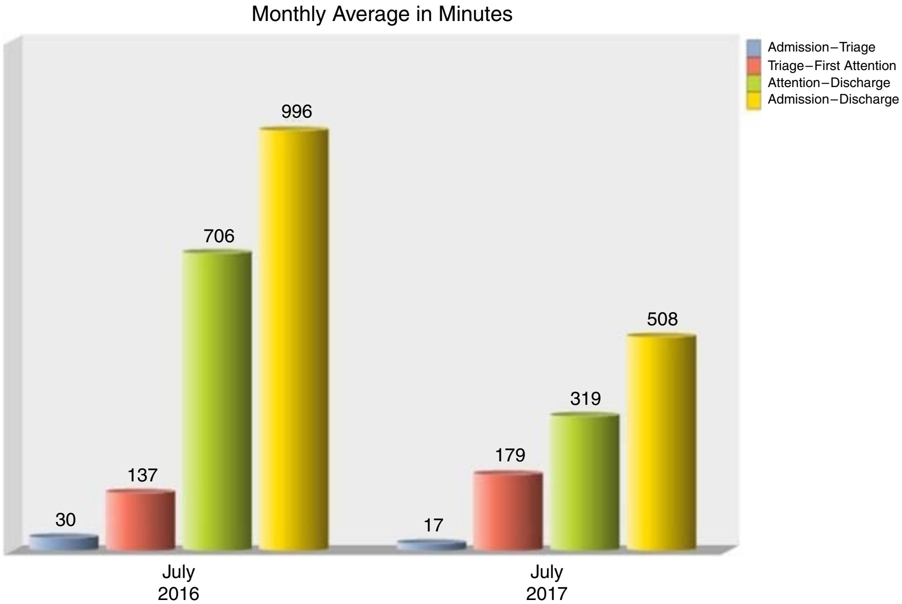

Figure 5.
LOS comparison July 2016–July 2017

The framework was applied to a single case at the ED of large Chilean hospital, including the active participation of its manager and MDs, providing plausible evidence that a formal design approach facilitates using specialized flows, proposed by modularity, by means of a more efficient structure than the silo, functional one hospitals usually have. Joint work of health professionals and academics made possible this work that produced good practical results, but, at the same time, generated innovations in health production design. Of course, being a single case, no general conclusions can be advanced, but it is a good starting point to replicate the experience.

The project generated a great value in terms of better service and good use of resources that increase capacity. Also, since most public hospitals in Chile operates in a similar way, there is an opportunity to replicate the solution in selected hospitals and generate similar value for them. We already have a proposal for doing this for the ED of other hospitals and an extension for inpatients.

Then, we conclude the plausibility of the idea we proposed that an important design problem in health services, in terms of potential improvements in capacity utilization, is production design. This provides the opportunity to reduce investing large amounts of resources in new hospitals and to instead use the alternative to generate large amounts of capacity by production performance improvements.

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