distinguishing themselves from others by value-based competition [6].
Thereby, the goal of this research is to propose an information system architecture that integrates the Hospital Supply Chain, in a way that all participants can access, exchange and analyze information on the same basis, and measure and share common performance indicators.

2.1 Methodology

The proposed methodology to optimize the hospital supply chain through an information system architecture that monitors and assists in the decision making of key processes is divided into three phases:

2.1.1 Phase 1: Identifying the Improvement Opportunities:
In this phase, a survey of information on the local hospital supply chain is carried out, checking the technology available and whether the chain is adhering to the 4Rs concepts [4]. After these surveys, a convergence between the information gathered focused on identifying opportunities for optimization of the chain is performed. Figure 1 shows the flowchart to conduct Phase 1.

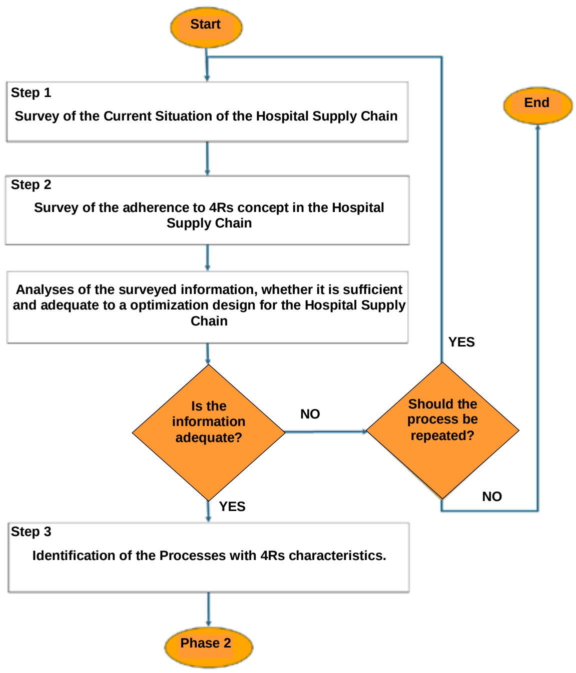

Figure 1: Flowchart for Identifying Improvement Opportunities in the Hospital Supply Chain – Phase 1.

To gather the information, interviews are held with the managers of the key processes of the hospital supply chain, key customers, and if necessary, professionals in the information technology and technical support areas.

1. In step 1, the information gathered should describe the characteristics of the key processes: Receipt of Products, Storage, Distribution of Products, and Requirement Planning, identifying the main operational limitations, with regard to: Processes: Describe the current process, its stages and flows.
2. Measurements: Identify the key performance indicators used and what is the expected performance, or service level agreed upon.
3. Decision-making: Evaluate the logics and criteria used by the management to carry out the decision-making and who are responsible for making them.
4. Technology: Identify the software used and the opinion of the managers on the adherence and efficiency of the systems, as to the needs. Also check if the systems are integrated and with which other systems. In step 2, the key processes are evaluated to identify the presence of 4Rs concepts:

Responsiveness: Identify the ability to answer the key processes of the hospital supply chain – CSH.

1. Reliability: Identify the level of reliability of the respondents in the delivery anticipated to the CSH key processes.
2. Resilience: The capacity of the CSH key processes for withstanding unforeseen disturbances and return to the initial conditions.
3. Relationship: As the processes are related among themselves and with further CSH links.

With the information surveyed, the processes that were accounted for the four concepts are eliminated from the analysis.

2.1.2 Phase 2: Optimization Proposal Based on the 4Rs concept:

In this phase, the optimization proposals necessary for the hospital supply chain to become more competitive are defined and detailed. It is also evaluated if the electronic information available in the control software used by the company can be used in the proposed optimization architecture. Figure 2 shows the flowchart for performing Phase 2.

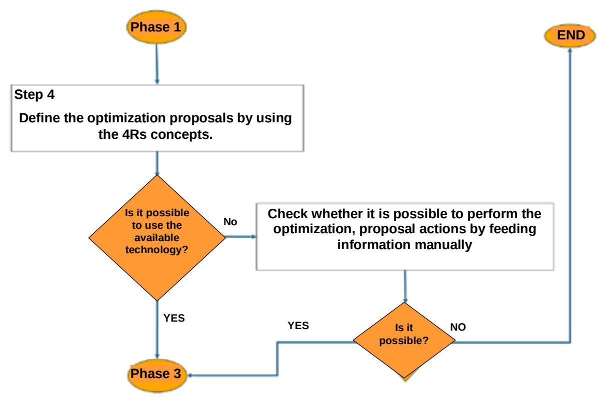

Figure 2: Flowchart for defining the Optimization Proposals Based on the 4Rs concept – Phase 2.

The optimization opportunities are arranged according to the competitiveness requirements of the hospital supply chain, which is the basis for the design of an Information System Architecture for the Optimization of the Hospital Supply Chain.

1. Processes: What are the improvements needed to control and standardize the key processes of the hospital supply chain.

Measurements: The measurements necessary to key processes such as: main indicators and service levels agreed upon in the Hospital Supply Chain. Decision Making: List the improvements needed for decision making, this column should be integrated with the quantitative information of the columns: processes and measurements. It is also checked whether the information is acquired directly from the existing control software and/or spreadsheets with manual completion will be used.

2.1.3 Phase 2: Design of System Architecture to Optimize the Hospital Supply Chain - ASOCSH:

At this phase, with the detailed optimization proposals, the information system architecture required for the feasibility of the optimization proposals is designed. This architecture may or may not be integrated with the inventory control systems or logistic control of the companies participating in the hospital supply chain. However, it uses the information from this software to generate information and assist in the implementation of actions aimed at the optimization and control of the processes that integrate the links of the hospital supply chain. After the implementation of the design, periodic reviews are required for adjustments. Figure 3 shows the flowchart for performing Phase 3.

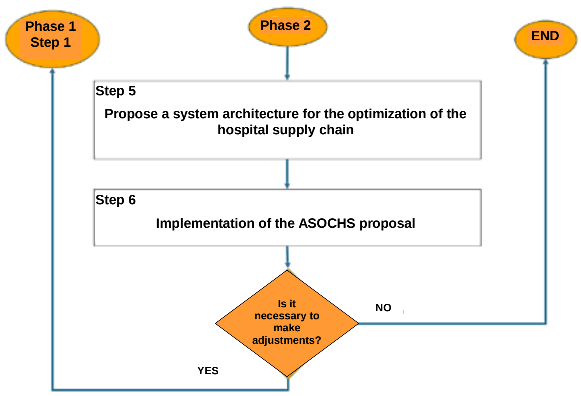

Figure 3: Flowchart for the execution of the Information System Architecture Design to Optimize the Hospital Supply Chain - Phase 3.

The proposed architecture uses an information hub - "framework" with the data from the hospital supply chain, from the receipt to the final use within the hospital, with the possibility of extending this acquisition of data down to the manufacturer, if necessary. The architecture is based on three interconnected modules: Information Hub Module, Indicator Module, and Decision Making Module.

This did not include the evaluation of the most appropriate technology for the implementation of the modules, but as a premise, the use of a cloud computing was used.

The modules are:

1. Information Hub Module: It is a hub (concentrator) for the most relevant data to optimize the chain and provides access to all participants of the local hospital supply chain. In this module, the data received from the control electronic systems or spreadsheets, manually fed of the hospital, are arranged through a key identifier, and are available for consultation. Data can be quantitative and relevant information to the hospital supply chain. The relationship of this module with the participants of this chain is shown in Figure 4 and has the function to receive the data individually and send information addressed to the indicators and decision support modules.

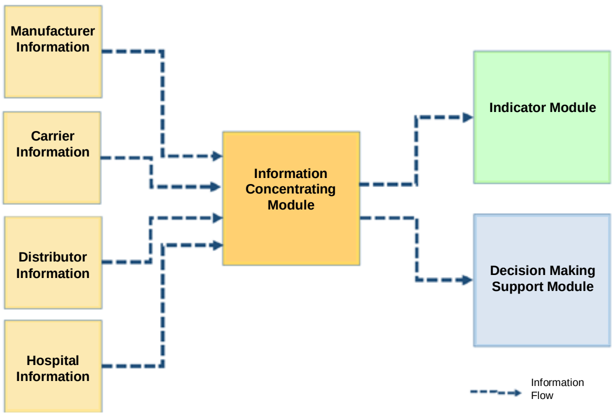

Figure 4: Graphic representation of the Information Hub (concentrator) Module and its integration with the participants in the hospital supply chain.

Indicator Module: Control system for the agreed indicators most relevant to the optimization of the local hospital supply chain. The model contribution to the proposed architecture is to build a set of indicators in line with the strategies of the company and adhering to optimization proposals. You must define a strategic focus with its clear objectives and integrate these objectives throughout the chain. In this module the result is a panel of indicators, with a maximum of twenty metrics. The function of these indicators is to monitor the tactical and operational objectives. They also provide information to metrics analysis, showing if they comply with the proposals for the optimization of the hospital supply chain. Their structure uses the Information Hub Module as the basis, and is presented to the participants in the chain through a control panel.

Figure 5 shows a graphic illustration of the integration of this module.

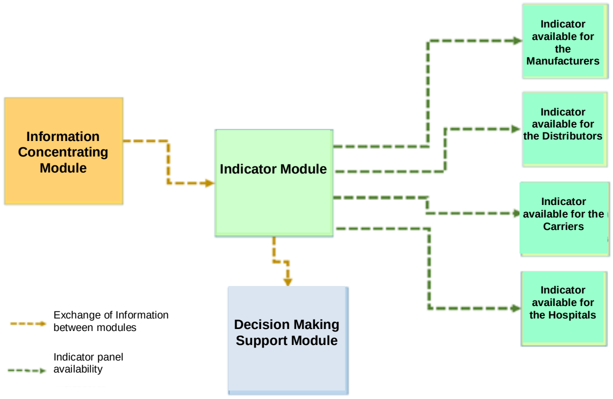

Figure 5: Graphic representation of the Indicator Module and its integration with the participants of the hospital supply chain.

2. Decision Making Support Module: This system will use quantitative and qualitative information of the Information Hub Module to perform the projections of scenarios required for the decision making. These decisions can be shared automatically among other participants of the hospital supply chain. The expected differential of this module is the possibility of using the information within the focused company, and, if necessary, among the other participants, to support the decisions that directly influence the optimization of the hospital supply chain. Figure 6 shows a graphic summary of this proposal.

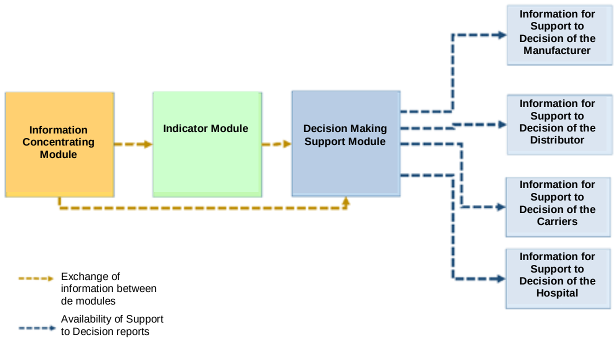

Figure 6: Graphic representation of the Decision Making Module and its integration with the participants of the hospital supply chain.

3 Application of the Methodology

The proposed methodology for system architecture for the optimization of the hospital supply chain - ASOCSH was applied to a hospital, with the characteristics described in Table 01, identified by Hospital 1, due to a confidentiality agreement.

Table 1: Hospital Characteristics 1

Hospital		
Data	Quantity	Amount in Reais
Beds installed	919	-
Operational beds	709	-
ICU Beds Installed	119	-
ICU Operational Beds	109	-
Surgery Rooms	32	-
Emergency Assistance (Year)	114.690	-
Surgeries Performed (Year)	26.405	-
Laboratory and Diagnostic Examinations (Year)	42.252	-
Number of Storerooms	6	-
Number of Pharmacies	10	-
Storeroom Average Inventory	-	19.567.106,75
Pharmacy Average Inventory	-	13.724.579,13
IC Average Inventory	-	33.291.685,88
Average Monthly Consumption	-	10.692.577,34

3.1 Application of Phase 1 - Identifying Improvement Opportunities:

For the purposes of Phase 1, the managers selected were: The person in charge of managing the storeroom e the person responsible for managing the central pharmacy. These two stores hold 60% of the hospital stock and that is where 52% of the entire hospital products are handled.

To analyze the information from the questionnaires conducted with the two managers they were consolidated into a single report.

3.1.1. Situation Assessment – Step 1

This stage lasted 30 days, and in addition to the interview with the storeroom and central pharmacy managers it was necessary to consult with other professionals related to the processes and information technology, since the managers were not able to answer all questionnaire questions.

For better organization of the method, the observations were consolidated according to the columns of the information gathering questionnaire, and the most relevant findings of this phase were:

1. Processes: The greatest difficulty was the need for surveying the entire process flow, since there were no formal drawings of the key processes and, therefore, the information needed to understand the details of the processes was not available. To support the key processes, there was a large amount of parallel processes, that neither the manager nor the professionals who perform the tasks had all information required, this way, the option was to make a macro process survey and draw a block diagram.
2. Measurements: There was no difficulty in identifying the key indicators, but there were no control of performance goals, it was not possible be sure of the actual performance.
3. Decision Making: A prior conversation with the manager was necessary to define the decisions that were relevant for him since this was not a practice to think about deciding, but about the problems generated by the decisions made.
4. Technology: Although this gathering does not require technical depth of information the managers did not feel confident enough to answer the questioning alone and it was necessary to request technical back up for the information technology and technical support professionals.

At this stage it could be seen that the managers showed many difficulties in obtaining information and thereby, a great difficulty in managing the key processes.

3.1.2. Evaluation Using the 4Rs Concepts – Step 2

1. This step took 15 days with one man-hour. For a better organization of the method, the observations were consolidated according to the columns of the information gathering forms, and the main findings were: Responsiveness: The concept understanding was easily learned by the managers and the answers were well grounded.
2. Reliability: For the reliability concept, the managers believed that the reliability was low and, as there was low reliability in all links of the chain they were not able to clearly illustrate the less reliable links.
3. Resilience: This requirement was difficult to understand and, at times, confused with responsiveness. It was necessary to present examples in order to proceed with the questionnaire. Relationship: The relationship was perceived as important and there were no difficulties in applying the questionnaire

At this stage, it was identified that the managers were convinced that these concepts are important for optimizing the CSH chain management, but due to lack of knowledge on supply chain management practices, the improvement actions are not evaluated.

3.1.3. Identification of processes have characteristics that identify the evaluated 4R principle - Step 3

In the questionnaire of step 2, the identification was carried out with the word "yes" for the processes with features that identify the evaluated 4R process, and with the word "no" to those which such features could not be found.

As none of the cases received a "yes" indication to all evaluated principles, no process was removed for the presentation of the optimizations in the next step.

3.2 Application of the Optimization Proposal based on the 4Rs Concepts:

The information gathered through questionnaires of steps 1 and 2 were synthesized and placed briefly focusing on the simplification of the actions.

3.2.1 Definition of the Proposals for the Optimization of the Hospital Supply Chain

The information resulting from measurement issues, proved to have content, even so, the indicators were used for integration between the main blocks of the process steps.

Table 2 shows the optimization proposals that were used as a basis for the next phase.

Table 2: Optimization Proposals for the Supply Chain Hospital 1.

Key Processes	Optimizations in Process Information	Optimizations in Measurements (Indicators)	Optimizations in the Support to Decision Making
Receipt of Products	Gather information on purchase orders (assignments): Assignments scheduled and received by supplier and item	Ratio of deliveries scheduled and received by supplier and item	Indication of assignments (service orders) that need to be scheduled and for what date
Storage	Gather information on the item kept in stock: code, description, average unit price, average consumption, balance, assignments to receive, inventory coverage.	Inventory value, Monthly Consumption, Inventory Product Coverage, Ratio of product orders received and order accomplished, Level of the service as to product compliance.	Indication of the products with coverage smaller than that recommended in the policy.
Internal Product Distribution	Gather information on internal requests: quantities separately delivered per order and item and time spent per delivery.	Ratio of orders and products performed effectively delivered (service level).	Indication of the level of service below the one agreed upon.
Demand Planning	Gather information on the consumption, planned: per quantity and value, and item. Information on stock balances and on essential production information with the origins and consumption of products per quantity.	Ratio between the consumption anticipated and accomplished (per product and per hospital), ratio between the consumption per area and the assistance production for this area.	Indication of the products with consumption anticipated below the actual consumption and those that are above

3.3 ASOCSH Design

As there were no unfavorable findings about the existing systems in the Hospital, according to required information, it was possible to continue the design without major restrictions.

But the same professionals have made it clear that the systems currently used would not be changed for this design, due to two reasons: cost and time.

Thus the proposed architecture followed the cloud computing premise with access via the Internet.

3.3.1 Proposal of a System Architecture for the Optimization of the Hospital Supply Chain - Step 5

Technical assessments on the best information technology and database were not considered in this work.

1. Information Hub Module Design:

The concentration of information was held in a database, open source software, and the information was acquired in two ways: direct feeding through spreadsheets with manual up-load, or directly from the database of the MV-Soul and Dynamics systems through the development of web services with data exchange in XML format. The main concern of this step was to size the data so it could be used in the following modules, for example, standardizing measuring unit and time scales for acquisition. Other calculations such as mean time, for example, followed the pre-existing settings in the hospital.

2. Indicator Module Design:

For this module it was necessary to define with hospital managers, standardized formulas for the calculation of indicators, through indicator index cards. After identifying the data required for the calculation, the next step was to analyze the data acquired by the process module was sufficient and in the same format. The main indicators defined were:

- Total inventory value: The value of the stock used follows the Brazilian legislation, i.e., the weighted average cost of the product multiplied by the quantity of the product kept in the stock.
- Average Monthly Consumption: Sum of the value of the consumption of products in the last twelve months divided by twelve.
- Stock Coverage in days: Balance of the quantity of the product in stock, divided by the average daily use (last 12 months).

With the key indicators defined, the indicator panel was sized, with access on the same screen for all

professionals working in the hospital supply chain of Hospital 1.
As the storage process is based on information for the receipt and distribution processes, the option was enter the information related to product inventories into the indicator panel, and other information was consolidated in reports.

3. Decision Making Support Module: This module used the same tools as the one used in the indicator panel to assist in the decision making. The basic premise was the simplification of the warning or decision calculations by always using data already gathered by the process module. The resulting information in this module is:

- Indication of product with less coverage than what is recommended - 60 days: The policy of Hospital 1 is to keep 60 day inventory coverage, just to provide decision support, for this optimization we used the indicator panel to signal the following conditions: no balance from 1 to 30 days, 30 to 60 days, and more than 60 days of coverage.
- Scheduling for receiving the products with less than 60 days of coverage: For this information a screen was created, integrated with the hospital HIS system, in which the manager can schedule the delivery of the product and if whishes so, to send an electronic communication, via e-mail for the supplier to know and confirm the product delivery schedule.

4 Implementation of the ASOCSH Design

The implementation of the ASOCSH design was carried out in accordance with the architecture modules, and the procedures performed for the implantation were:

- List of the necessary data, treatment concerning the measurement and time unit.
- Definitions of the information that would be sent directly by web services and which would be updated by excel spreadsheets.
- Programming of the open source database software called "MySQL".
- There was no evaluation for the best technology, only tests to find out whether data was available as needed.

Further, for the indicator module, the procedures performed were:

- Programming of the indicator panel by using the PHP language.
- The resulting screen, Figure 8 shows the indicators defined in the design: Total Inventory Value in Reais, Average Monthly Consumption in Reais, and Coverage in days.

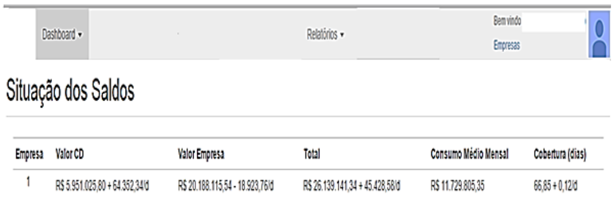

Figure 8: Indicator Module Screen

For the Decision Making Support Module, the access was programmed through the indicator panel. The main information, for the support to decision set in the design was:

- Indication of products with a coverage smaller than what is recommended – 60 days,
- Schedule for receiving the products with less than 60 days of coverage, and

Figure 9, shows the decision making support module, indicating the products with less than 60 days of coverage, divided as the design settings: no balance, 1-30 days, 30-60 days, and greater than 60 days of coverage.

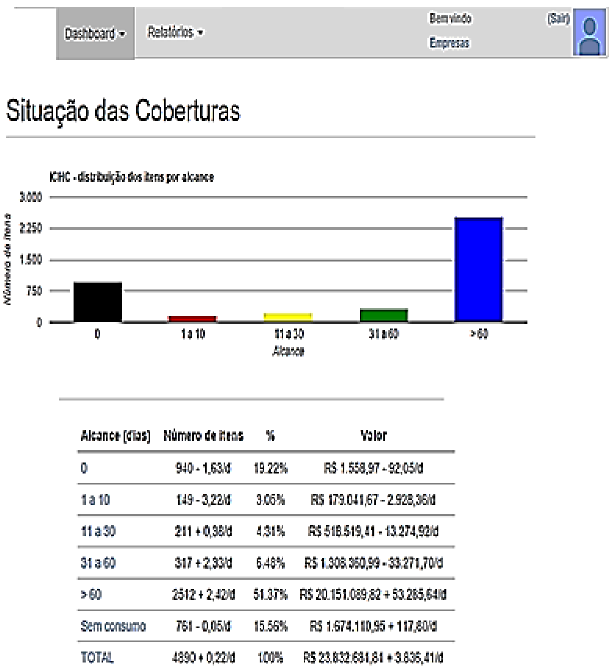

Figure 9: Graphic screen of the Decision Making Support Module.

On the same screen, Coverage Status, the period is selected to prepare the delivery schedule. The report to program the schedules is generated automatically with information on: balances, amount available for the delivery schedule (Qty, Performance, Total), Coverage, and if there is already a schedule for the product.

4.1 Main Results of the ASOCSH Design

With the Information Hub Module, it was possible to access the most relevant information for the management of the hospital supply chain, with the originally planned features, namely:

1. Available adequately: The information referring to the hospital supply chain was separated into two electronic systems, MV-Soul and Dynamics, in addition to spreadsheets without formal control of version and data. With the module, it was standardized and organized in one single place.
2. Accessible when needed: The information was made available through the Internet at any time.
3. Using the required accuracy: There were many problems due to the understanding of the information pattern such as: product unit, data reference period, and information nomenclature, which were corrected by the organization of the Module Database units. The Indicator Module was responsible for the major change in the way of acting of the hospital supply chain professionals. Prior to the operation with the support of ASOCSH, there was no actual measurement by the key indicators; so the management was carried out according to specific problems and without monitoring of the action efficiency. With the implementation of the methodology, and subsequently, the indicator module, the management began to be held based on the key indicators, switches, and the monitoring of the effectiveness of these actions, directly and quickly in the ASOCSH. Another significant advantage of this module was the possibility of discussing the problems and solutions between managers and senior management, with direct access to the indicators in real time, adding one more resource required to the information that is the sharing feature. The main result of the decision making support module is to automate the decision-making process, which, even though simple, has greatly increased the process reliability. This module added speed and accuracy to the key decisions and, because of its way of operating, with access via the Internet, the reliability and collaboration requirements were potentialized in the processes focused by the module. In summary, the implementation of the ASOCSH proposal, with quick access to information, integrated with the modules, enabled managers to check the variations of the indicators correct the problem and monitor the results in real time.

As the Hospital had a very big problem of product shortages, even with a total stock of R$ 23 million, equivalent to 2.8 months of coverage, the main focus of the managers was not to reduce the stored values, but rather distribute the stocks better.

However, with the operation supported by the ASOCSH, the inventory managers increased the accuracy in purchase orders, decreasing unnecessary purchases, and thereby, after six months of operation, the stock was reduced by R$ 7.3 million, or approximately one third of the total.

Table 3 shows the inventory values in the first 6 months of the operation with the support from the ASOCSH.

Table 3: Inventory values in the first 6 months of the operation with support from the ASOCSH.

Operation Month with the Support of ASOCSH	Inventory Value (Million Reais)
Month 1	22,8
Month 2	19,8
Month 3	18,2
Month 4	17,5
Month 5	16
Month 6	16

Even with a smaller stock, products with coverage between 1 and 60 days, increased by R$ 5.2 million, more than 2 times from the first to the sixth month of operation. With more availability of products shortages decreased, which was perceived by the increase in service level measured by the indicator Module. In addition to increasing amounts of stored products covering between 1 and 60 days, the values of stored products with coverage larger than 90 days diminished to R$ 10.5 million or 75%, i.e., the distribution of the products in stock, according to coverage, was more balanced, reducing shortages and leftovers. Figure 12 shows the graph of stored product values, divided by coverage range, in the first 6 months of operation with the ASOCSH.

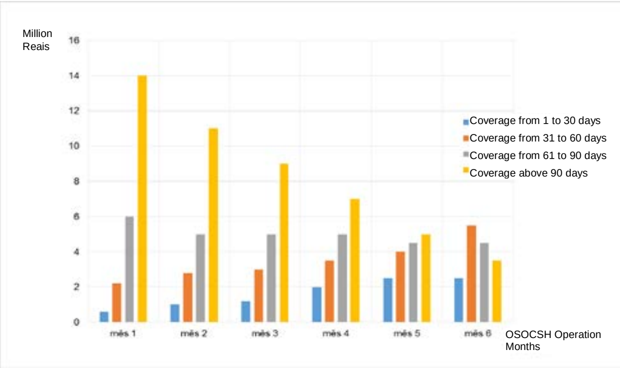

Figure 12: Graph of Stored Product Values, divided by the coverage in the first 6 months of operation with the ASOCSH

5 Conclusion

This study shows a methodology and design of an information system architecture for the optimization of the hospital supply chain management.

Based on these studies and the author's experience, a methodology and a design for the optimization of hospital supply chain n was developed through an information system architecture based on three modules, called Information Hub (concentrator), Indicator, and Decision Making Support. To evaluate the proposal, the methodology was applied to a large scale Hospital.

With the application of this methodology to the Hospital, it was found that its supply chain had some deficiencies that hindered the administration, such as, for example, the managers did not have information that could assist them in identifying problems, bottlenecks and improvement opportunities. With the application of the System Architecture design for the optimization of the Hospital Supply Chain (ASOCSH), the perceived contributions were:

1. With the Information Hub Module: the data required to optimize the management was identified, organized and stored in one location, with the possibility of quick access at any time.

2. With the Indicator Module: It was possible to measure the performance of the key processes, identifying bottlenecks, need for improvements, and monitor the results after deployments.

3. Decision Making Support Module: The key decisions that were made without adequate information and, therefore, had little effect, started to be made based on accurate information, at the right time, with few mistakes and very efficiently. As there was not a culture of measurement and control of the performance indicators for the processes of the hospital supply chain, it was not possible to quantitatively compare the results before and after the ASOCSH. However, it became clear that after six months of implementation, there was an optimization in the management, as confirmed by the performance indicators, monitored by the tool. As it can be seen in the graph of stored product values, divided by the coverage range, Figure 30, before the ASOCSH there were many stocks with more than 90 days of coverage and few stocks with 1 to 60 days of coverage. After six months of operation, the stored product values were within the ranges between 30 and 90 days of coverage, greatly reducing the product shortages and unnecessary inventories. As in the Hospital of the study, the locations for the storage of the products were small or outsourced; the reduction of stored volumes and fewer movements diminished the direct cost with storeroom rental and losses due to breakage in the storage processes and product picking activities.

With the proposal of the National Health Surveillance Agency – ANVISA to create the National Drug Control System (SNCM), Law No. 11903-2009, the ASOCSH can be integrated with suppliers and execute functions such as: planning of collaborative demand, CPFR - Collaborative Planning, Forecasting, and Replenishment, and shared inventory management between hospitals and suppliers, VMI - Vendor Managed Inventory or CRP - Continuous Replenishment Program. It was not possible to define the exact values saved and/or best used with the ASOCSH design, since some data did not have permission to be used and published, but we certainly can state that there was an optimization of stored product values, and thus improving the acquisition of products for the hospital.

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