Implementation of Advanced Warehouses in a Hospital Environment – Case study

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Abstract. In Portugal, there is an increase of costs in the healthcare sector due to several factors such as the aging of the population, the increased demand for health care services and the increasing investment in new technologies. Thus, there is a need to reduce costs, by presenting the effective and efficient management of logistics supply systems with enormous potential to achieve savings in health care organizations without compromising the quality of the provided service, which is a critical factor, in this type of sector. In this research project the implementation of Advanced Warehouses has been studied, in the Hospital de Braga patient care units, based in a mix of replenishment systems approaches: the par level system, the two bin system and the consignment model. The logistics supply process is supported by information technology (IT), allowing a proactive replacement of products, based on the hospital services consumption records. The case study was developed in two patient care units, in order to study the impact of the operation of the three replenishment systems. Results showed that an important inventory holding costs reduction can be achieved in the patient care unit warehouses while increasing the service level and increasing control of incoming and stored materials with less human resources. The main conclusion of this work illustrates the possibility of operating multiple replenishment models, according to the types of materials that healthcare organizations deal with, so that they are able to provide quality health care services at a reduced cost and economically sustainable. The adoption of adequate IT has been shown critical for the success of the project.

1. Introduction

Recent studies show that the healthcare sector is going through great changes with healthcare organizations suffering huge pressures to reduce costs and to increase healthcare quality (de Vries, 2011; Lee, et al., 2011). The healthcare costs in Portugal are increasing, essentially as a result of three factors: the aging population, new technology investments (and the associated labor costs) and the increased demand for healthcare (Pinto, 2008). Besides that, the efficiency of the National Health System is low and, the financial debt is high, even though it has been decreasing lately (Carvalho, 2010).

To provide healthcare services was for years the main concern of healthcare organizations, regardless of the associated costs. With the increase of costs associated with material managing and due to the severe competition between healthcare institutions, the importance of the Supply Chain Management (SCM) increased focusing on maintaining a good cost-efficiency ratio without compromising the service quality (Callender & Grasman, 2010; Carvalho, 2010). The main focus of the SCM is to reduce the associated costs of material and information flow management without reducing the service quality, acting as a critical factor on its organizational performance and on gaining advantage towards competitors (Lee, et al., 2011). Although the SCM practices have been proven effective in other industries, with considerable improvements, the results on the healthcare sector are far from the same level of improvement (McKone-Sweet, 2005; Rosseti, 2008; Kelle &
Schneider, 2012). For many authors, healthcare organizations cannot reduce costs due to inefficiencies in the SCM (Schneller & Smeltzer, 2006; de Vries, 2011). In the past few years the large number of studies performed on economics, logistics, operational research and administration, has contributed to develop and improve the healthcare sector. These studies show an increased concern with the inventory management since, drugs and medical consumables, typically accounts for the second largest expense in the hierarchy of hospital’s costs. Therefore, special attention must be given to materials management, with a huge potential intervention in terms of logistics management (Schneller & Smeltzer, 2006; Nabais, 2009; Carvalho & Ramos, 2010; Landry & Beaulieu, 2010b).

This paper shows the results of a study conducted at Hospital de Braga (HB), in order to improve the process of material supply in patient care units, increasing the visibility of material flow, reducing inventory levels, and simultaneously increasing the material’s availability. The project involved the reorganization of processes in the Central Warehouse (CW) and the implementation of the Advanced Warehouse (AW) concept for two clinical departments: Angiography and Central Operating Room (COR). The new system which integrates three different supply models (par level system, two-bin system and consignment system) for different types of materials, is supported by an information technology (IT) system, which allows users to know, in real time, the stock of material along the whole process, and to ensure its efficient management.

The paper is organized in six chapters: the next one is a theoretical framework on approaches to healthcare organization’s logistic system; Chapter 3 describes the case study; Chapter 4 describes the implementation of the AW concept in the HB; in chapter 5, the results will be analyzed and discussed regarding the impact of this implementation; The main conclusions are described in the last chapter.

2. Literature review

According to the Council of Supply Chain Management Professionals SCM “includes the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management. It should be noted that the SCM involves the coordination and collaboration between partners, whether they are suppliers, logistics providers or customers. In essence, the SCM integrates supply and demand management within and across companies” (Carvalho, 2010).

The SCM in hospitals includes the external supply chain (e.g. suppliers, distributors, etc.) and the internal supply chain (e.g. hospital facilities, warehouses, patients, etc.) (Landry & Beaulieu, 2002; Rivard-Royer, 2002; Schneller & Smeltzer, 2006). A hospital receives goods and services from suppliers and then stores and distributes them to various patient care units, according to the operating process. Internally, the hospital has a complex distribution network, which usually consists of warehouses that provide stocks of medical supplies to patient care units (Landry & Beaulieu, 2002).

The specific context of the healthcare sector differs from the industrial sector, as its main mission is to provide healthcare services to patients (Landry & Beaulieu, 2010a). However, to provide healthcare services to patients, healthcare institutions need material resources. These institutions need to make significant investments in material resources to ensure proper healthcare services. Effective management of materials can lead to huge savings in these organizations, while the definition of robust stock management policies is essential to deal with the complexity associated with materials consumed (Carvalho & Ramos, 2010). Recent studies show that improving the stock management results in increased savings and revenues (McKone-Sweet, 2005; Rossetti, 2008).

Inefficient management of stocks can cause excess of or material shortage, leading to consequences for the healthcare organization. On one hand, excess inventory conducts to high holding costs, which leads to the risk of products becoming obsolete. On the other hand, the lack of inventory may result in stock-outs, which in the healthcare industry can mean dissatisfaction among healthcare professionals, delays in surgery, and in extreme situations, in the death of patients (de Vries, 2011). In these circumstances it is normal healthcare professionals wanting large amounts of stocks (Landry & Beaulieu, 2010a). Many healthcare organizations remain hesitant when it comes to reducing inventory levels, since the costs associated with the lack of material are much higher than the cost of having additional inventory (Aptel & Pourjalali, 2001).
The distribution of materials to patient care units of healthcare organizations is usually performed in two ways: the distributor delivers the material in the hospital’s CW, and the CW is responsible for storing and delivering the material to the patient care units; or the distributor (or CW after receiving) delivers the material directly to the patient care units, and there is no storage in the CW – nonstock items (Egbelu et al., 1998; Aptel & Pourjalali, 2001; Landry & Beaulieu, 2010b). This requires the establishment of collaborative relationships in the supply chain, by emerging collaboration concepts adopted in the healthcare industry (Carvalho, 2010). In order to integrate the internal and external supply chains, the practice of stockless materials management programs began to appear in this sector (Rivard & Royer, 2002). In this practice, distributors are responsible for the supply and distribution of material directly to the patient care units eliminating one connection in the supply chain, the hospital CW (Landry & Philippe, 2002). In the definition of Vendor Management Inventory (VMI), the stock management becomes the supplier’s responsibility. The supplier controls the amount of inventory in the hospital (customer) according to information on inventory consumption and has replenishment stock responsibility (Carvalho, 2010). In cases where customers have more power, the stock is at the customer facilities and on consignment. Hospital Professor Doutor Fernando Fonseca (Neves, 2009) and the Centro Hospitalar de Lisboa Norte (Carpenter & Viegas, 2012) have implemented VMI. The consignment is defined according to Lee (2008) as the process in which the supplier puts the material at the customer’s facilities, without receiving payment until the material is consumed. In an audit carried out in Portugal by Carpinteiro and Viegas (2012) all audited hospitals, a total of six, acquire medical supplies on a consignment basis. Some of these cases are the Hospital of Vila Nova de Gaia/Espinho (Teixeira, 2012) and the Hospital of Santa Maria (Nabais, 2009).

The supply of material to patient care units plays an important part of the hospital’s internal supply chain. Thus, through an adequate supply of material, an organization can achieve lower operating costs by reducing investment in inventory handling and improving service levels, providing better healthcare to patients (Perrin, 1994). The distribution process of materials to patient care units can be accomplished in several ways. A number of replenishment systems were adopted by the hospitals, over time and across the world, which are reported in the literature. The most traditional replenishment system is the requisition system. In this system the healthcare professional controls the process of decision when and how much to order (Wolper, 2004). Despite being simple and with low investment, it generates extra requisitions, unnecessary high stock levels or unacceptable low stock levels, and takes up too much of healthcare professionals time (Perrin, 1994; Osorio, 2009). For many years the trend has been changing the traditional system for the exchange carts system, relieving healthcare professionals of the replenishment task (Perrin, 1994). In this system, the material is placed on a movable cart positioned in the storage unit. Another identical cart with exactly the same stock is prepared. The cart trading is done according to a predetermined schedule by the second cart (fully stocked). The first cart returns to the CW to be replenished and later will replace the cart that is in the storage unit (Landry & Beaulieu, 2010a). According to Wolper (2004), this system requires a large investment in carts and the inventory is duplicated. At par level system when the inventory quantities are below the established level, the material is restored to the maximum level. Some hospitals use a min-max variation of this system (Wolper, 2004; Landry & Beaulieu, 2010a). The par level system is implemented at Vila Nova de Gaia/Espinho’s hospital, supported by IT (Teixeira, 2012). In the two-bin system, each item is stored and distributed over two containers. The material is only removed from one container. When the first container is empty the healthcare professional uses the second container. Before that, the need for replacement is identified. This can be done in several ways, from identifying the withdrawing label of the product and adding it to a specific location, sending the empty container to the CW to be restocked, etc. The Kanban method is used to set up the signal (Landry & Beaulieu, 2010b; Leone & Rahn, 2010). Later new practices associated to the two-bin system arise, like RFID-enable two-bin system and e-kanban (supported by an IT system) (Landry & Philippe, 2002, 2004; Bendavid, 2010). This system is implemented in hospitals in various countries like USA, France, Japan, Portugal, among others (Landry & Beaulieu, 2010). Portugal Pulido Valente’s Hospital (Lima, 2007) and Santo António’s Hospital already adopted this system (Fontes, 2005). Other systems were
introduced, like automated storage cabinets, which were developed as a way to link patient consumptions with supplies, and weight control bin method, where the replenishment is triggered when the bin reaches the preset weight for each product type (Landry & Beaulieu, 2010b). According to Bendavid et al. (2010) U.S. hospitals are adopting the RFID-based cabinets for high value products. Each replenishment system has its own advantages, disadvantages and ways of operation. However according to literature review conducted under this project, healthcare organizations have been adopting only a single replenishment system for the distribution of medical supplies.

3. Medical supply distribution in Braga’s Hospital
HB is integrated in the National Health Service’s network and provides healthcare to about 1.2 million people in the districts of Braga and Viana do Castelo (Braga Hospital, 2015, paragraph 3). The hospital’s internal chain includes 1 CW and 69 storage units. The CW is a large warehouse, with a large number of material references (higher than 1600) and with the main function of supplying all storage units. Each storage unit works as small-scale storage points, located within the patient care units which they supply, allowing healthcare professionals to gain quick access to the materials. On HB the medical supplies are classified under three categories according with the supply strategy:
- **Storage material**: material with high turnover, usually common to several clinical departments, and stored in the hospital’s CW, hence the name of storage material. This type of material can be divided into two sub-categories:
  - **Material without registration**: covers all materials where it is not possible to register it to patient’s treatment, such as caps, gowns, garbage bags, and more.
  - **Material with treatment’s consumption record**: the materials used during the treatment are recorded and associated with the procedure and the patient, such as syringes, needles, etc.
- **Specific material**: specific material for specific clinical departments, usually characterized by being low movers material and in most cases with a high cost (e.g. catheters). This material is delivered directly to the patient care unit without the need for storage in CW (cross –docking).
- **Material on consignment**: The management of consigned material is the supplier’s responsibility. The hospital only has the responsibility to pay after using it. This type of material is not stored in the CW and is delivered directly to the patient care unit, getting stored in the storage units (cross–docking). The cost of such material is generally very high and such materials are only for specific specialties (e.g. implants). Cross-docking operations represent 53% of all hospital’s CW receptions.

The replacement of medical supplies in the patient care units is performed in three replenishment logistic systems according to the type of material.

3.1. Replenishment systems

3.1.1. Two-bin system. The replacement of the storage material, without or with consumption registration, is performed through the two-bin system with Kanban cards. Kanban is a card that is associated with two boxes of material and consists of a label with the product barcode. The barcode information allows you to obtain the material’s specifications and the amount to be restored.

Healthcare professionals start by taking material from the first box. When the last material unit drive ends (leaving an empty box) the Kanban card is removed and placed in a separate box (unread cards box), where the cards are to be scanned, and then they start to take the material from the second box. These cards of empty boxes are read by PDA (Personal Digital Assistant) from the storekeeper and a request is made to the CW to pick up the requested products. The Kanban cards that are in the "unread cards box" are moved to "read cards box". The request of material is triggered by the material consumptions - Kanban signal. The replacement of requested materials is held on the same day. Once the materials are replaced, cards are placed again, from the "read cards box" onto the respective product box. At the hospital there is a weekly plan already established that sets the number of times per week that the storekeeper has to scan the needs for each patient care unit. In some cases, the material requested by the patient care unit may be in stock-out in CW. As a result there is no
replacement of these materials, through the cards from “read cards box” to the "unread cards box" so that the next scanning needs to be read back again. This does not allow healthcare professionals to understand whether the material is in stock-out in CW or if that material has already been delivered and consumed. The reordering point in a two-bin system was calculated considering an average consumption in a period between replacements, more another day - safety stock. This replenishment model combines features of continuous and periodic review models since, every review period (fixed-interval), if the quantities in stock are below the minimum (kanban signal), a fixed order is placed (one box) to achieve the maximum level (two boxes).

3.1.2. Requisition system. The replenishment model used for the specific material is the traditional or requisition’s system. In this model, healthcare professionals are responsible for monitoring and controlling material inventory levels and to place orders to Purchasing department, when they consider it necessary. According to healthcare professionals this task takes, on average, about 1 of the 12 working day hours. This time was not timed but indicated by healthcare professionals based on their experience. In this type of materials only a maximum level is defined. These levels are defined by clinical personnel together with the Logistics department.

When the specific material is delivered to the CW, an input and an output of the material is given on the IT system, which means that the material is marked as consumed even before reaching and being available for use at the specific patient care unit. From this moment on, there is no more control or tracking information of this material.

3.1.3. Consignment. In consignment, the supplier is responsible for stock management. After the consumption of this type of material healthcare professionals just need to register on a specific sheet the material that was used and send it to the Procurement department where an input and an output is given at the same time of the correspondent material on IT system ,before make the purchase order. In this replenishment model, all consignment materials have a maximum level. This level is defined by Logistics department along with suppliers and with the clinical personnel. The replenishment policy is based on the following assumption: whenever there is consumption of a unit, the supplier restores a unit of this material.

The control of the material is limited. Although the supplier has the responsibility of stock management there is no control of the material that is placed in the hospital by the supplier or the material quantities available in storage units. This is because the HB has neither the function to check or to give input and/or output of the material delivered by the supplier. In addition the logistic process, since the consumption until the registration of consumed material, is set in different locations and times, by more than one agent, and by the use of paper.

Table 1 summarizes the main problems encountered in the existing replenishment systems. Based on this analysis there is a need to get involved through the development of this project in order to remove the limitations found.

| Replenishment system   | Problems                                                                 |
|------------------------|---------------------------------------------------------------------------|
| Two-bin system         | - Difficulties on matching the patient’s consumption records;             |
|                        |   - Different times between the need to and the request of a material replacement; |
|                        |   - Difficulty in identifying if the material has been consumed or is in stock out in CW. |
|                        | - Healthcare professionals are responsible for stock management ;        |
|                        | - Nursing deviation from their main tasks;                              |
|                        | - Low inventory and consumption control.                                 |
| Requisition system     | - Low control of the material delivered in hospital facilities by suppliers; |
|                        | - Consumption to record process is bureaucratic and happens in different places. |
4. Proposed solution

After identifying and analyzing the existing problems in the replenishment systems, the adopted solution was to use AW which are an extension of CW, acting as supermarkets, supported by IT system. The AW model is based on: par level system for specific materials and storage materials with treatment’s consumption record; two-bin system for storage materials without registration; and consignment model for consigned materials. The operation of all models is supported by the IT system which allows a connection of the records of product consumption and the stock levels. These three systems will operate at the same time working in parallel on the same patient care units. This approach is innovative because in other hospitals where AW concept is implemented, it is only based on one replenishment system. These hospitals typically use or par level system or two-bin system.

This solution was initially implemented in Angiography unit due its low activity and reduced levels of medical supplies and consequently in COR which is a service with high activity levels, with large amounts of material of different specific clinical departments (representing 50% of total consumption of HB materials). Of the total stock value of these two patient care units and the CW, Angiography represents on average 2.85%, COR represents 39.15% and CW represents 58%.

4.1. Par level system implementation.

Through the implementation of AW concept with par level system, all materials stored in AW have associated a maximum and a minimum level on the IT system. While the maximum level is the maximum possible amount to own, the minimum level corresponds to the reorder point. This replenishment system is the engine of min-max system. If the quantity is below the minimum level, an order is triggered with a fixed amount (difference between maximum and minimum level). In this system, the traceability of the products is high allowing the user to know in which AW are certain products, at a given instant. Material consumption records are performed on time and the levels are instantly updated on IT system. Material registration is essential, matching real stock on the ward with the stock on the IT system, since the absence of it causes a mismatch between them.

4.1.1. Treatment’s consumption record material. The consumed materials are no longer being replaced by the two-bin system and they are replaced through the AW concept using par level system. In this new model the maximum levels are the same but the minimum levels are decreased to reduce inventory levels due to the fact that the minimum level does not need to be half of it (one box in the two-bin system). This reduction is possible since the patient care unit supply is performed on the same day. This system provides a proactive replacement with more automated and timely replenishment orders (at the time of consumption), without the need for a storekeeper to go through all the clinical departments to read the material needed. These materials represent 46.1% of all materials value.

4.1.2. Specific material. With the AW concept implementation with par level system, the healthcare professional fails to monitor the stock levels of specific materials, passing the responsibility to Procurement department to analyze material’s levels. The products that have less than the minimum level are followed by a purchase order to the respective supplier.

The supplier’s material is received in the CW’s receiving area, recording all items received on the IT system in the respective AW, by reading the bar code with reference, batch and expiry date. When there is consumption, the healthcare professionals register all the material’s data into the IT system. The minimum and maximum levels were defined based on the last 12 months purchases activity since there were no records of consumption, to cover the service for a month. These levels are justified for being in an early stage of the project, therefore it was important to have a bigger safety margin. Control of this type of material increased considerably. Previously, the only control that existed was when an input and an output was given on the IT system, after the material was received in the CW. It is now possible to know when the material arrives, when it is consumed and when there is need for replacement in a patient care unit, the level of quantities, among others. The specific material in AW replaced by par level system, represents approximately 7.1% of all materials value.
4.2. Consignment

The request of consigned material, unlike the previous process, is triggered by the registration of consumption in patients care units at the time of their use by the same agent (healthcare professionals). The replenishment system is exactly the same as practiced until now. Whenever there is material consumption, the unit is replaced. After receiving the material in CW, the entry record is given on IT system consignment model, by reading the barcode with the reference, batch and expiry date.

Every day an email is sent to the suppliers specifying which material has been consumed. This email is sent even if there is no consumption of any product to avoid possible confusion next to the supplier, because if it is only sent when there is consumption, any problem sending emails, it could easily be interpreted by the supplier as lack of consumption even if it had existed.

In this new model the responsibility of material management remains with the suppliers. However, there is more control of products that are delivered by suppliers to the hospital facilities. In addition the IT system does not allow the suppliers to deliver material that does not belong to the material list agreed between the hospital and the suppliers. The consignment material in AW represents 27.7% of all materials value.

4.3. Two-bin system

Replenishment process of storage material without registration continues to be held by the two-bin system with Kanban cards. The two-bin system is already established and implemented in most hospital patient care units and it is suitable for use with this type of material. Therefore it continues to be implemented in AW of the patient care units. The Logistics department already has a solution planned for giving feedback information to the healthcare professionals in case of stock-outs in CW, by placing a paper saying "Stock out" in the container where the material should be placed. As a result, healthcare professionals know what materials are in stock out in CW. The material in AW replaced by two-bin system represents 4% of all materials value. The rest 15% of all materials value are related to the non-resident consignment material (material that are not in the hospital facilities, only used in specific interventions and that arrives on the same day of the respective intervention).

5. Result’s analysis

Regarding material with treatment’s consumption record, the material replenishment is based on consumption records, allowing firstly, detect the need for replacement faster (at the time of use) and secondly, make the orders automatic (picking request is made by IT system to the CW).

With regard to the specific material, the great advantage of this implementation is that the management of those materials is no longer the responsibility of healthcare professionals and becomes the Logistics’ responsibility, freeing about 8% of the healthcare professionals working time to other activities, thus improving healthcare quality. There is also greater material control with access to inventory levels in real time and with the information of consumptions records in patient care units the replacement becomes then triggered on the basis of consumption.

At consignment, in addition to the improved material control delivered to the hospital, it was also possible to cut down on paperwork during the logistics process, since previously consumption recording was made on a sheet in patient care unit, before being sent to Procurement department to record the consumption on IT system.

In addition to the benefits previously mentioned, it was also possible to obtain other advantages. One of them is related to the expiration time control. It is possible to alert healthcare professionals to consume first the materials with shorter expiration time. Another important aspect was changing the management of specific materials to consignment basis. These materials have a very high cost and by managing on a consignment basis it was possible to reduce stock capital costs. However some materials are not yet on consignment basis since they are already in stock and paid for. Thus these materials only swap after being consumed.

With the development of this project these three replenishment systems coexist in the hospital supply chain, running in parallel according to the type of medical supplies (Figure 1):
Figure 1. Hospital Supply Chain with AW concept in use.

Table 2 shows the stock units and references before and after the AW concept in Angiography and COR is implemented. With this system we were able to obtain an average holding stock value reduction of about 28.2% in Angiography. The increase number of references in Angiography may be justified by reduced stock outs, i.e., due to the fact that they weren`t available in this store unit before this implementation.

**Table 2.** Stock averages before and after the implementation of AW in Angiography and COR.

| Patient care unit | Date                | Stock units | References |
|-------------------|---------------------|-------------|------------|
| Angiography       | Before AW implementation | 511         | 32         |
|                   | After AW implementation | 634         | 45         |
| COR               | Before AW implementation | 28573       | 964        |
|                   | After AW implementation | 32152       | 1017       |

With regards to COR, the average value of holding stock was reduced by approximately 4.6% with the implementation of AW, even with the increasing number of units and number of references, like in Angiography (Table 2). This value will be further reduced with the material changeover from specific to consignment.

The COR`s material service level increased considerably. This calculation is based on the number of requests that were satisfied by the CW into the COR. The service level went from about 91% to about 97% with the AW concept implementation (Table 3). The high level of service requests is partly justified by the high inventory levels in AW and due to the fact that it started recently.

**Table 3.** COR service quality before and after the implementation of AW concept.

|                       | Total requested units | Total satisfied requested units | % satisfied requested units |
|-----------------------|-----------------------|---------------------------------|----------------------------|
| Before AW implementation | 813952               | 736879                          | 90.79%                    |
| After AW implementation  | 621697               | 605728                          | 97.43%                    |
6. Conclusion
Due to rising material costs and increased competitiveness in this sector, healthcare organizations felt the need to develop an economically sustainable material management that at the same time could provide quality healthcare services to patients. It is essential that the medical supplies are always available for patient’s treatment and that healthcare services take place normally. Logistics is then a key role to support inventory management, supply and distribution policies so that the service level is not affected.

Before this project was in place, the patient care unit’s supply process still used old-fashion methods with the participation of healthcare professionals, and with inefficient management and control of stocks by Logistics department, resulting in high stock levels of certain materials and disruptions with other materials. The impact of the AW concept in the hospital's patient care units is huge since it reduces inventory levels, reduces the associated costs with material management, increases service level, and improves control over stocks and satisfaction level of healthcare professionals and patients.

Although this implementation has advantages it also presents some challenges: In certain materials there is a mismatch between the real stock and the IT stock, affecting the material’s replacement. This gap is due to the fact the records of materials consumed are not always made by healthcare professionals, the fact that other clinical departments withdraw material from Angiography and COR departments, and in COR, there is stock in the surgery rooms.

With the development of this project, we intend to give relevance to the complexity of the supply chain of healthcare organizations, as well as the large number and variety of materials that these organizations deal with daily, and demonstrate that the integrated operation of several replenishment systems, according to the category of the material, may result in benefits for these organizations. Besides that, it is essential to note that IT plays an important role to improve the performance of the replenishment process.

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