UNIVERSITY OF TWENTE.

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Background material: Appendices

To analyze and improve Tyco's Sprinkler Supports in the field of (de)installation efficiency

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Report for completion of bachelor's assignment

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Abstract (Dutch)

Het doel van deze opdracht is de installatie-efficiëntie van pijpophangingen in sprinklersystemen te verbeteren. Dit zal gebeuren door middel van 5 herontwerpen.
Het verbeteren van de installatie efficiëntie is in dit verslag gedefinieerd als het verminderen van de arbeid, verkorten van de installatieduur en het verlagen van de kosten. Niet alleen het installeren zelf wordt beschouwd, maar ook de logistiek eromheen, aangezien dit erg wordt beïnvloed door aanpassingen in een ontwerp. Bij logistiek moet gedacht worden aan het bestellen, verpakken en transporteren van de onderdelen.
De vraagstelling van deze opdracht is dan ook: Wat is de huidige consumptie van tijd, arbeid en geld gedurende de installatie, en hoe verloopt de logistiek? Verder zal ook bekend worden wat de klanten voor wensen en problemen hebben rondom de installatie.

De resultaten uit deze vraagstelling zijn:

- een concurrentieanalyse
- een approval-analyse
- een productanalyse van 5 producten uit Tyco's pijpophangingen assortiment (deze analyse focust zich op de geometrie van componenten, hoe ze zijn verbonden en de volgorde van assemblage)
- een klanteninterview
- een analyse van de tijdsverdeling van een sprinkler installatie
- en een anlayse over de installatie kosten

De conclusies hieruit zijn verwerkt in een plan van eisen dat de input is voor de 5 concepten.
De voornamelijkste conclusie is dat pijpophangingen *te* flexibel zijn opgebouwd; de meeste componenten kunnen worden aangepast, individueel vervangen worden en hebben vaak maar 1 functie. Een dergelijke opbouw zorgt voor veel componenten, oftewel; een ingewikkelde installatie. Terwijl al deze mogelijkheden niet nodig zijn voor sprinkler ophangingen.
Het morfologische schema, gepresenteerd in hoofdstuk 11, laat dan ook voornamelijk oplossingen zien met weinig componenten.

Echter, de echte herontwerpen richten zich meer op het verlagen van de arbeid. Het knippen van draadstangen, draaien van componenten en het openbuigen van pijphangers is daarom zoveel mogelijk voorkomen. Getracht is om deze acties onnodig te maken voor de klant en om de assemblage zo kort en makkelijk mogelijk te houden.

Of dit is gelukt is echter nog de vraag. Het gros van de concepten verlaagt de installatie arbeid. Maar of ze daadwerkelijk tijds- en geld efficienter zijn moet nog blijken. Een opvolger zal deze tests opzetten en uitvoeren.

Concept	1	2	3	4	5
Componenten	2	3	3	2 (of 3)	2
Assemblage stappen	8	9	10	10	9
Knippen stang	Nee	Ja	Ja	Nee	Ja
Opdraaien componenten	Nee	Nee	Ja	Nee	Nee
Openbuigen hanger	Nee	Ja	Ja	Ja	Nee
Extra component nodig om te zekeren	Nee	Nee	Nee	Nee	Nee

Abstract (English)

The goal of this assignment is to improve the installation efficiency of sprinkler piping supports. This will be done by making 5 redesigns.
In this report, improving installation efficiency is defined as reducing the consumption of recourses during installation. The recourses being; labor, time and money. Besides installation, the logistics around it are also considered. This is because adjustments in a product's design influence this area greatly (logistics are; the packaging, transporting and ordering of components). The main question for this assignment therefore is: What is the current consumption of time, money and labor during installation, and what are the arrangements for the logistics? Furthermore, the wishes and problems of the customers will become clear in this report.

The results of this question will be:

- a competitive research
- an approval analysis
- a product analysis on 5 of Tyco's sprinkler supports (this analysis focuses on the components' geometry, connections and assembly order)
- customer interviews
- a time analysis of sprinkler installation
- a money analysis of sprinkler installation

The conclusions from these analyses are implemented into a schedule of requirements which would be the input for the 5 redesigns.
The main conclusion is that the pipe support structure is *too* flexible. Most of the components can be adapted, individually replaced and often only have one function. Such a structure contains many components, or in other words; results in a complicated installation. This is a shame since these possibilities are hardly functional in a sprinkler support. The morphological schedule, presented in chapter 11, therefore mostly shows designs with only a few components.

However, the final concepts focus more on the reduction of labor consumption. The cutting of the rods, pivoting of components and bending of the hangers have therefore been avoided as much as possible. This was all done to make the assembly as short and easy as possible.

Whether or not the redesigns have succeeded in improving installation efficiency remains the question. Most of the concepts reduce labor consumption, but nothing is known yet about the possible reduction of time and money consumption. A successor will test the concept on those aspects.

Concept	1	2	3	4	5
Components	2	3	3	2 (or 3)	2
Assembly steps	8	9	10	10	9
Cutting rod	No	Yes	Yes	No	Yes
Pivoting components	No	No	Yes	No	No
Bending hanger	No	Yes	Yes	Yes	Nee
Extra securing element needed	No	No	No	No	No

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Ch.1 Introduction

Building systems, they are not fully understood by architects and often concealed under false ceilings. They are a vital part of our daily lives because working or living in an unventilated, unprotected or unheated room can result in health issues or reduced performance. Yet, hardly any attention is given to these building systems after installation. An inspection is done every now and then, bored inhabitants or employees may stare at a ventilation grid and sometimes the setting of a system is changed. This is especially the case with sprinkler systems; once they have been installed they are expected to function properly for the whole lifespan of a building.

1.1 Tyco fire protection products

This assignment is carried out for Tyco, a company specialized in the distribution of building system components such as fire sprinklers. The company also sees a shortage of attention given to building system components. Installation companies focus on the performance and functionality of a system, but not necessarily on the installation part of it; how fast pipes can be suspended, how easily parts can be connected, it is all considered less important. This way of thinking resulted in system components being made from very standard, widely applied elements, which often need resizing, reshaping and pre-assembling before they can be put to use inside the system. The goal of this assignment therefore is to improve the installation efficiency of one of these components within the sprinkler system; the pipe supports.

1.2 Introduction

Chapter 3 will give some information about the working and layout of sprinkler systems and will explain what Tyco does and sells in this market. Chapter 4 will successively describe Tyco's current market position and will give an idea about the competition in sprinkler supports. The analyzing of Tyco's supports will take place in chapter 5, describing the current efficiency in support installation. To do this, it had to be clear what efficiency actually is. It seems a hard notion to define, an explanation in percentages seems the easiest method. However, the business dictionary[1] is usable, describing the term efficiency as following: "The comparison of what is actually produced or performed with what can be achieved with the same consumption of *resources*". It also states that is an important factor in determining productivity. So, to analyze and improve the pipe supports on installation efficiency, the right resources merely had to be picked. The choice fell on; labor, time and money. 'Money', because the buyers of the products do not install them, the workers do. The product therefore needs to be advantageous in the eyes of the purchaser in order to be sold. 'Time', because quicker installation means more tasks can be performed. This will result in more money to be made. And 'labor', because the consumption of this resource defines the true efficiency in installation. If a task can be performed with fewer installers, can be done easier, or even not be performed at all, it will affect both the money and time aspect of efficiency. Chapter 5, 6 and 7 describe these analyses and the current consumption of these three resources. Sequentially it was tried in chapters 10 and 11 to reduce this consumption in order to increase efficiency. Here the concepts for improving the installation efficiency of sprinkler pipe supports are presented.

1.3 End Goal

To realize this, an end goal was formulated:

"Through redesign; reduce labor, time and money needed for the customers to deal with the installation of Tyco's sprinkler supports."

Note that the words 'to deal with' were used when talking about installation. This was done to include the area of logistics into the assignment. To merely focus on the installation would be narrow minded. Because, changing a product's geometry also changes the way it is packed, transported, and sometimes even how it is ordered (in parts or as a whole). Large, negative changes in these logistics could neutralize the advantages obtained by changing the product's geometry.

The end result of the assignment will be concepts, specified with global construction drawings and a list of improvements or added values. It is up to the next person in this follow-up assignment to test whether or not these concepts comply with the global installation guidelines and to test whether or not they can be successfully integrated into the assortment

Ch.2

Background information

2.1 Company layout

This assignment is executed for Tyco's sector Metal framing & pipe supports EMEA in Enschede. To give an impression on Tyco's organization this chapter is added; it shortly describes Tyco's business and markets which are all over the world. The company layout is roughly portrayed in figure 1.

Tyco is a diversified, global company that provides thousands of products and services[2] [3] all around the world. To make business easier the distinction Americas, EMEA and AsiaPasific is made, EMEA being the area of Europe, Middle-East and Asia.
Each sector roughly produces the same products; ranging from electronic security, water purification and fire-fighting equipment[10]. These products are divided into three business segments; security solutions, flow control and fire protection. The first segment provides electronic security and fire protection, closed circuit television, access control, critical condition monitoring, electronic article surveillance and advanced security integration. The sector flow control manufactures valves and controls, water and environmental systems and thermal control solutions for industries, enabling customers to improve operating efficiency and minimize risk. And the last segment, fire protection, supplies customers with special-hazard protection, emergency communication and supplied air solutions to customers on land and sea. This segment includes a metal framing and pipe supports sector which is housed in Enschede. Metal framing & supports is a merger of many international sales and distribution companies. Therefore Tyco's product range is very wide and contains products from suppliers such as; Unistrut, Wopf, Lindapter, Acroba and Debro.

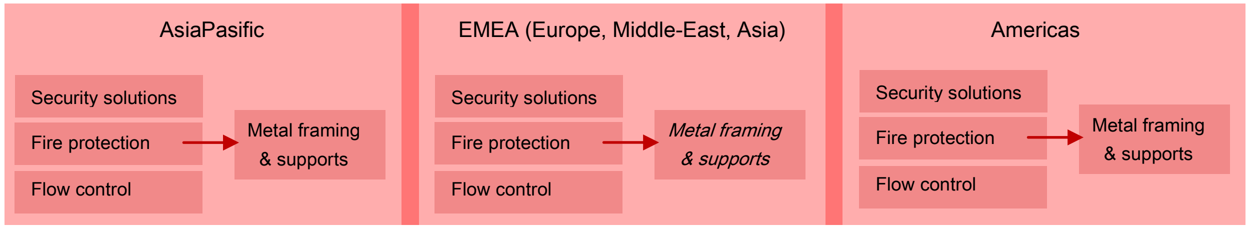


Figure 1: Company layout

2.2 Sprinkler systems

The sector metal framing and pipe supports sells products suspending the components of a sprinkler system. The most common component is a pipe, so this sector mainly sells hangers and clips. Also consoles and frames are sold, when they are necessary, this is often the case when other systems lay their piping in the same area. There are four main types of sprinkler systems, they can all be suspended using the same supports, but the size of the pipe and the place on the ceiling determines what support to use. The four types are: wet pipe, dry pipe, deludge and pre-action.

- Wet pipe systems. These systems are most common. They have few components, resulting in relatively fast installation. Water filled pipes keep the sprinkler heads pressurized, but when the temperature rises to 70-140℃ a glass bulb in the sprinkler head will shatter, letting the water flow.

- Dry pipe systems. Dry pipe systems are used in situations where moisture levels vary and temperatures can drop below freezing. These systems are at high risk for corrosion because when the system is not in use, small amounts of water remain together with oxygen filled air. The stored water is released after a sensor in the sprinkler head detects fire.

- Deluge systems. This system is implemented in high hazard situations where risks of rapidly spreading fire are high. They are similar to wet pipe systems, only they have open sprinkler heads and empty pipes. When an alarm goes off, a mechanical deluge valve in the pump is opened.

- Pre-action systems. Pre-action systems are combinations of dry pipe, wet pipe and deluge systems. They are used when accidental activation is very unwanted, for example in computer rooms or libraries. Besides the sprinkler system, a detection system needs to be installed. This system will send a signal to open the pre-action valves in case of fire. This signal will open the pre-action valves, filling the pipes with water, when this happens, the system will function as a wet pipe system, having closed sprinkler heads which need their glass to shatter before water is released.

The piping layout for all these systems differs, but the same principle applies; large diameter pipes close to the pump, small diameter pipes deeper inside the building. In normal situations, only a few larger diameter pipes are needed. But pre-action and deluge systems often have a different set-up. Since generally only parts of the building are high hazard, a separation between high hazard areas and low hazard areas has to be made. In these cases, more pipes of a larger diameter are needed to supply water to each individual room. Figure 2 shows a basic layout for sprinkler pipes[9]. Main pipes are the largest pipes and often run vertically. Mains are the first to come in contact with water from the pump and are often held in place using fixed point supports. These supports are very suitable for handling axial forces. The first horizontally running pipes are the crossmains, these transport water to the branchlines which have smaller diameters. Holes are drilled into these branchlines to create openings for springs, armovers, return bends or drops which transport the water to the sprinkler heads[9]. The supports used to suspend these pipes are standard; the same type of support, only in different sizes, can be used to suspend all pipes. With the exception of the fixed point supports, these specific supports are needed for main lines and at the ends of branchlines to absorb axial forces. And of course, when there is a lot of variation in the roof types, different methods for anchoring the supports are needed.

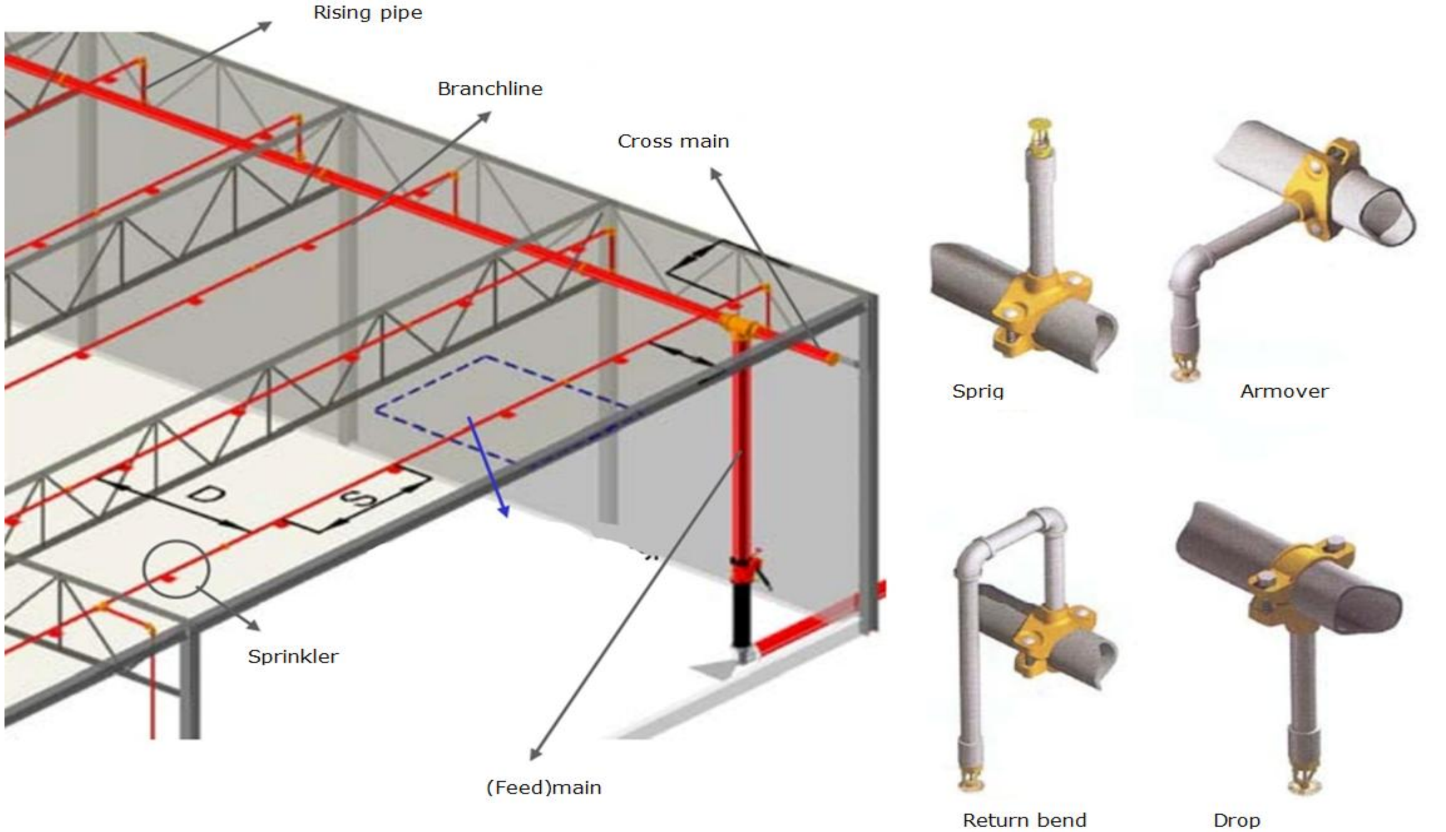
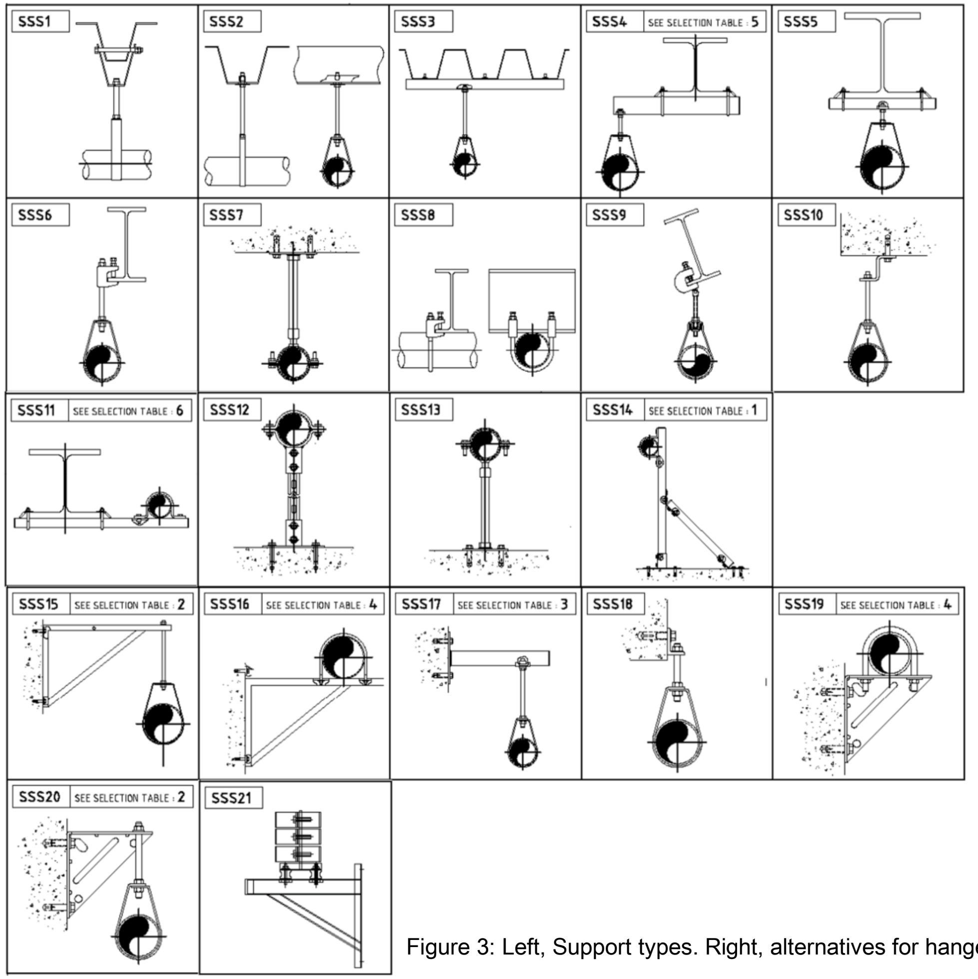


Figure 2: Piping layout sprinkler system

2.3 Tyco's sprinkler supports

The supports for sprinkler pipes are often standard. And as can be seen in figure 3, the *components* within these supports are also standard. Threaded rods, hangers or channels can be found in virtually every sprinkler support. The figure shows the index of Tyco's sprinkler support catalogue[13]. This catalogue was created to make the ordering of components more easily for customers. It gives a clear overview of all types of sprinkler supports Tyco has to offer.



There are about 30 products, but about 100 combinations are possible, this is because the hanger (pipe surrounding component) can often be replaced with a pipe clip or other types of hangers[11]. The 30 products are subdivided over 21 product ideas, which are categorized into four connection types:

- Ceiling connections (sss1 - sss11)
- Floor connections (sss12 - sss14)
- Wall connections (sss15 - sss20)
- Fix point connections (sss21)

Floor connections are hardly ever used in sprinkler systems, as well as wall connections. And as said before, fix point connections are needed in small amounts in every sprinkler system. The ceiling connections however, are used a lot, but also vary a lot. It is hard to determine which one is used most often. With trapezium roofing; sss1, sss2 and sss3 are common types, with steel beams; sss6 and with concrete plated roofs a simplification of sss10 is often used. This last support is then ordered without the Z-fitting, only needing an anchor, threaded rod and hanger to suspend a pipe.

These products come in different sizes, most of them suitable for suspending pipes with nominal diameters between 25 mm and 200 mm. As a note, sprinkler piping is often painted red, so these supports are suitable to let pipes slide through them in the stages of assembly without damaging the painted coat.

Alternative pipe surrounding components:

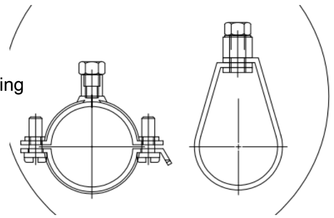


Figure 3: Left, Support types. Right, alternatives for hanger

Ch.3 Competitive research

Previous chapter stated that virtually all sprinkler supports are created with the same, standard components. This standardization means that companies having these components in stock may attract customers in search of sprinkler supports, even though this was not the original purpose for having these components in stock. It also leaves the option for customers to buy the different components from different distributers. For example, hangers and anchors are cheap at company A, but threaded rods are cheaper at company B. Customers can decide to order their parts for supports from different companies. For companies without strong customer contact, this leaves a risk for loosing market. To identify how Tyco stands in the sprinkler support sector a competitive research is done.

This competitive research is loosely based on Porter's 5 Forces model[14 15]. This model explains how 5 forces determine the competitiveness of a market; the suppliers, buyers, development, new market entrants and existing competitive rivalry. For starting a business this is a good model to use since it analyzes a market's potential. In the case of Tyco this is not relevant, since they are already a strong player in the sprinkler support market. However, the model also determines the overall attractiveness of a market, showing how Tyco currently stands in between these 5 forces, and for the sake of the assignment, it will hopefully show in which area Tyco can move to have the least hindrance from these 5 forces.

3.1 Power of suppliers

Tyco has two main suppliers for metal framing and supports, these are Unistrut UK and Wopf Germany. They supply more than half of Tyco's sprinkler supports. The rest of the products come from companies such as; Lindapter, Acroba and Debro[12]. Since Tyco has multiple suppliers and is not fully dependent on one of them, it can be said that this force does not threaten Tyco's possibilities to make money in this market. When all suppliers decide to stop delivering, Tyco can always decide to order elsewhere, this is possible because the sprinkler supports are made up of standard components.

3.2 Power of buyers

Tyco's sells sprinkler supports to medium and large installation companies. These companies may specialize in the installation of sprinkler systems, but can also install HVAC systems (heating, ventilation and air conditioning). They are often situated in the Netherlands, the rest of Europe or in the Middle-East. Seeing that there is a large spread of buyers, it can be said that Tyco is not dependant on one of these individual companies.

3.3 Product and technology development

The threat of substitution of components in an installation company's assortment is large. Sprinkler supports contain multiple components, which are standard and use standard methods for connecting. This leaves room companies to develop better or cheaper components with plans to offer them to installers. Installation companies can then choose to only buy this one component from this company, which is then slowly taking over market share. Seeing that many companies try this (slightly improving or cheapening components), it can be said that the force of development is a large threat within the support market. It therefore is necessary for Tyco to keep innovating.

3.4 Threat of new market entrants

Since there already are many companies selling sprinkler supports, the arising of new competitive companies is a low threat. They would first have to claim a significant market share and become trustworthy before they can become a threat to Tyco. On top of that, the customers in the installation business are often conservative; once they have a set of components they order each time, they are not keen on switching from components or products.

3.5 Existing competitive rivalry

Chapter 3.2 stated that Tyco has a wide spread of customers. However, seeing that companies sell similar components the competition is large. Buyers can easily switch suppliers. Appendix A, pages 1-7 roughly shows the existing rivalry; giving an overview of a number of components on the market which positively differ from Tyco's. It gives an idea of the of products Tyco is competing with.

Conclusion: Tyco has to strengthen its developments in products and technologies and has to keep fighting the existing competitive rivalry in order to maintain market share. The other three forces (market entrants, suppliers and buyers) are not a large threat for Tyco's current position in the market of sprinkler supports.

Logistics around installation

The goal of this assignment was to reduce the labor, time and money needed for the customers to deal with the installation of Tyco's sprinkler supports. In order to do this, the current assortment had to be analyzed, which is done in chapters 5. However, this chapter will focus on how customers currently *deal with* the installation, *excluding* the actual installation processes. In other words, this chapter explains the current logistics around installation.

There are three main elements within logistics. These elements are: ordering, packaging and transport. These three were chosen because this is where customers come in contact with the products and because these areas are considerably affected when changes are made in a product's design.

4.1 Ordering

Tyco's sprinkler supports catalogue is used to order the supports. The first step is to pick a right product for the right situation. For example, a trapeze roof needs multiple pipes to hang from it. The customer looks at the index as in figure 3 and chooses product sss3 because this is most suitable. The customer than finds the corresponding information inside the catalogue and sees a list of components as in figure 4. As can be seen, this list of components is quite long for merely one product. On top of that, each pipe size requires a different set of components. All in all; for a customer not used to this type of ordering, this method of information transfer is complicated. A support which contains few components and can be used for multiple pipe sizes or multiple pipe height seems more logical.

Tag#	Qty	Description	Size	DN25	DN32	DN40	DN50	DN65	DN80
1	3	Jack nut M6 Finish 5	Size Art. nr.	M6 8SJN	M6 8SJN	M6 8SJN	M6 8SJN	M6 8SJN	M6 8SJN
2	1	Channel UNI2 Finish 2	Size Art. nr.	L=660mm UNI20660	L=660mm UNI20660	L=660mm UNI20660	L=660mm UNI20660	L=660mm UNI20660	L=660mm UNI20660
3	1	Channel nut Finish 5	Size Art. nr.	M10 3910064	M10 3910064	M10 3910064	M10 3910064	M10 3910064	M10 3910064
4	1	U-shaped washer Finish 5	Size Art nr.	M10 30mm 3913010	M10 30mm 3913010	M10 30mm 3913010	M10 30mm 3913010	M10 30mm 3913010	M10 30mm 1373011
5	1	Hex nut DIN 934 ¤: Finish 3, 4 or 5	Size Art nr.	M10 934¤M10	M10 934¤M10	M10 934¤M10	M10 934¤M10	M10 934¤M10	M10 934¤M10
6	1	Threaded rod ¤: Finish 3, 4 or 5	Size Art. nr.	M10 x 1m 975¤M10X1M	M10 x 1m 975¤M10X1M	M10 x 1m 975¤M10X1M	M10 x 1m 975¤M10X1M	M10 x 1m 975¤M10X1M	M10 x 1m 975¤M10X1M
7	1	Sprinkler hanger Finish 2	Size Art. nr.	DN25 SUDN2510	DN32 SUDN3210	DN40 SUDN4010	DN50 SUDN5010	DN65 SUDN65	DN80 SUDN80
8	3	Hex bolt DIN933 ¤: Finish 4 or 5	Size Art. nr.	M6 x 25mm 933¤6X25	M6 x 25mm 933¤6X25	M6 x 25mm 933¤6X25	M6 x 25mm 933¤6X25	M6 x 25mm 933¤6X25	M6 x 25mm 933¤6X25
9	3	Washer DIN9021 ¤: Finish 3, 4 or 5	Size Art. nr.	M6 9021¤M6	M6 9021¤M6	M6 9021¤M6	M6 9021¤M6	M6 9021¤M6	M6 9021¤M6

Figure 4: Support catalogue[6] : component list sss3

How customers order can also differ. Some installation companies order in large batches, some order per project. Ordering in batches means the installation company has a warehouse or storage area to stall components until they are needed. Ordering per project means that components are delivered to the installation site directly. This can only happen with pre-engineering. Pre-engineering is when a building's geometry and the layout for piping is known beforehand. An architect does this by precisely designing the 3D layout of all installation systems, determining exactly what pipe diameters need to hang how high and where. He or she does this in consultation with the installers of all building systems. The option to order in large batches can also benefit from pre-engineering. After the system layout is known a company can decide to get components out of storage, and pre-assemble them before taking them to the installation site. This method of ordering in large batches and pre-assembling reduces the workload on the installation site, but increases the overall transportation costs.

30% of all companies orders in large batches, 70% orders per project.

4.2 Packaging

Components are delivered in separate cardboard boxes (some in batches of 100). The boxes contain plastic bags and are stacked in larger boxes or on pallets. How and where the customer unpacks the products depends on the type of ordering and the preference of the customer. Some unpack everything at the installation company; this leaves the advantage of not dragging packaging materials to the installation site. Others unpack everything at a centralized place on the site, and a rare group of installers partially unpack components at the very last moment; on the place where they need to be hung. These last two options create a shorter hands-on-tool time on the installation site, meaning more time is spend doing activities other than installing or assembling supports.

4.3 Transport

Tyco's delivery time is no longer than 48 hours when components are in stock. When they are not in stock, this may take up to 6 or 8 weeks. Currently, the costs for transporting are calculated in weight, volume and distance of the components. Meaning that; small, light packages transported over small distances are most efficient.

In current logistics, some traveling stages can be recognized, the components follow the path: supplier → Tyco → customer or installation site → hang location → (dump)
Since these first two stages cannot be influenced by the customer, they are therefore left out of this chapter. The last stages from customer to hang location are most important because this is where the customers have contact with the components, influencing the real transport efficiency. To find out exactly how
transport takes place on the installation site, customer interviews were held.

Phases	Ordering per project	Ordering in large batches
1. Planning	Needed components are ordered and delivered to the construction site. Spare parts (5%) are brought by installation crew	Components are periodically ordered and delivered to the installation company. Whenever possible, components are unpacked, pre-assembled and pre-grooved. Assembly area and stock area must be present.
2. Gathering required resources	Crew: 2-20 Tyco delivers components to site. Transport on site: carts, buckets, crates Crew brings tools for installing supports: gloves, drill, rod cutter, anchor setting tool, waterlevel/laser. Scaffolding on wheels is rented.	Crew: 2-10 Company hired transportation delivers components to site. Transport on site: heftrucks, buckets, crates Crew brings tools for installing supports: gloves, drill, rod cutter, anchor setting tool, waterlevel/laser. Scaffolding on wheels is rented.
3.Setting up environment	Components are unpacked. Centralized area is set up and arranged as assembly area. In some cases supports are assembled by workers on their carts individually. Scaffolding is put in place.	Multiple areas are set up for optimal distribution of components to workers. Scaffolding is put in place.
4. Executing the job	Per pipe installation: Ground crew: 2 material transport (1), assembly (1) Ceiling Crew: 3 support montage (1), pipe suspension (2)	Per pipe-installation: Ground Crew: 1 material transport (1) Ceiling Crew: 3 support montage (1),pipe suspension (2)
5.Assessing how things are going	TIME data about installation is preferred, hardly ever obtained.	TIME data about installation is preferred, hardly ever obtained.
6. Make changes to improve execution	Innovation is looked at, sometimes new products are tried, but hardly ever implemented	Innovation is looked at, sometimes new products are tried, but hardly ever implemented
7.Concluding job	Area is cleared, tools are gathered	Area is cleared, tools are gathered

Figure 5: Transport of tools, components and people around the installation site

3 Project leaders of the installation companies Wolter & Dros[4], De Groot Installatiegroep[5] and AA Fire Protection[6] were interviewed. These are experienced companies which all install sprinkler systems in the area of Enschede. Asked was how they arrange transport of components, tools and personnel on and to the building site. The results can be seen in figure 5. This table shows 7 stages in task performing. These stages were derived from Harvard's Customer Centered Innovation map[17]. It describes how a customer's job can be thoroughly mapped to discover opportunities for breakthrough products and services. This research makes it possible to describe any task in 8 phases, making it possible to categorize any problem, but it also makes it *im*possible to overlook a problem if all actions within these phases are thoroughly considered. One phase is left out, the phase of confirming readiness to begin (actual phase 4), this is done because this phase requires no explicit tasks in sprinkler installation. Also, the distinction of ordering in large batches and ordering per project is yet again made. This is done because the ordering in large batches requires a different transport route; components need to be taken to the installation company first.
The figure shows the main difference between the types of ordering; the place for pre-assembly. Companies ordering in large batches often pre-assemble at their own company, while companies ordering per project pre-assemble on the installation site. But the most striking is that *all* parties pre-assemble. There even was one party that pre-assembled in its own workshop, without using pre-engineering. This means they could determine the geometry of the supports, without knowing the exact roof geometry. This raises the question whether or not the supplier or Tyco can take up the task of pre-assembly, since they often have the same information installation companies do, but have better opportunities for automation. Other companies, ordering per project, often knew exactly which supports they needed, but still had to pre-assemble. When suppliers or Tyco would do this would mean less work for the installers and less transported volume since merged components result in overall less packaging material and smaller volumes

Conclusions: supports with few components, small packaging volumes, long hands on tool times, which are suitable for multiple heights and widths, which can be assembled early on in the supply chain and need few tools to install are efficient in installation.

Ch.5

Analyzing supports

As mentioned before, the goal of this assignment was to reduce the labor, time and money needed for the customers to deal with the installation of Tyco's sprinkler supports. In order to do this, analyses had to be done. Previous chapter described the analysis of the current logistics around installation. This chapter will describe the analyses done on the supports.

The main investigation subject is how the supports can be adjusted so that labor needed for installation can be reduced. The quantity and geometry of the components seem important; they determine the number of assembly steps and the types of tools. The life-cycle seems important as well, components with short life-cycles need to be easiest to replace. Otherwise, making adjustments could take up a lot of time. And also, the adjustability potential of a support is very important, because this determines the place where components can be assembled (the earlier in the supply chain the better, chapter 4).

With this information, a suitable method for analysis could be picked. The choice fell on Durmisevic's Transformable Building Structures[16]. This method focuses on the modularity and flexibility of structures and how component design influences this. It seems an unobvious choice, since sprinkler supports need to be fixed instead of transformable; they need to be hung, and will hopefully hang for a long time without human interference, until they are ready to be demolished. However, when striving for opposed results, this method will suffice very well. Imagine the opposite of a transformable construction; it will be rigid, has fewest parts possible and does not have to be changed until demolished or removed. An ideal scenario for sprinkler supports. Hopefully, using this analysis, it will become clear where and how supports can be changed to reduce labor consumption.

5.1 Choosing products for analyses

Since the catalogue contains 30 products and the time span for this project is short, only 5 of these products were selected for analyses. Only the most suitable supports were picked for analyses. 'Suitable' in this case being complex products which are often sold. Complex supports were selected from the catalogue because they contain a lot of components (a lot meaning more than 15). Estimated was that complex products would contain the widest spectrum of components, these products would show the widest spectrum of problem areas. Frequently sold products were suitable because it would be useless to make adjustments to supports that were hardly ever sold.

Products had to be selected which had both criteria. To do this, weighing factors were added. The complexity of products was rated and given a weighing factor of 2 1/3, the sales numbers per product were also rated and given a weighing factor of 1. This last factor is lower because the sales numbers of fiscal year 2011 were not conclusive to accurately show which support was sold most frequently. Since this data was not reliable, this criterion was given a low weighing factor.

Using these weighing factors, the top 5 products suitable for analyses could be listed. These products were: sss3, sss4_3, sss13, sss14_2 and sss18_2. Appendix B, pages 8-10 describes the full selection process.

5.2 Method

Durmisevic's method of Transformable Building Structures describes 3 analyses; a functional decomposition, technical decomposition and physical decomposition. This last one is subdivided into a life-cycle coordination, geometry of edges analyses and assembly sequence analyses. The goals for these analyses are to determine the functionality of components, the relations between components, how they are assembled and when or why they need to be adjusted or removed. How these analyses were performed and what the conclusions were can be read in this chapter. Only sss3 will be fully considered, the analyses on the other products can be found in appendices C-G, pages 11-41.

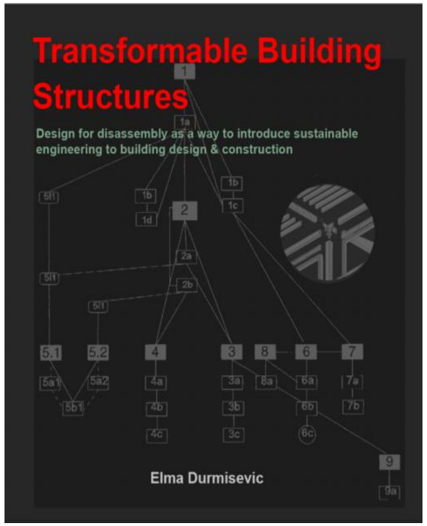


Figure 6: Design method Transformable Building Structures[12]

Before the analyses could start, the data needed to be synchronized. This had to be done because current data, the catalogue, did not have a usable system when looking at multiple supports. Component numbers did not correspond to a specific component, but rather to a certain component within the product. So as a first step, an overall list of components was made and numbered, containing all components described in the catalogue. This list can be found in the appendix. After this the analyses could start.

5.3 Functional decomposition

A functional decomposition gives information about a component's independence; this can either be functionally separated or integrated. Integrated components fulfil multiple functions. Separated components fulfil only one functions, or less, when multiple components are needed to fulfil one function.

In flexible structures, it is advantageous to have functional separation, because then, a product's functionality can easily be adapted by removing single components. No large sections of product need to be adapted to realize a change in functionality. However, sprinkler supports are more fixed than flexible, therefore functional integration has more advantages. To determine which type of functionality applies to the sprinkler supports, the functions of the components were listed. The functions of sss3's components can be found in figure 8.

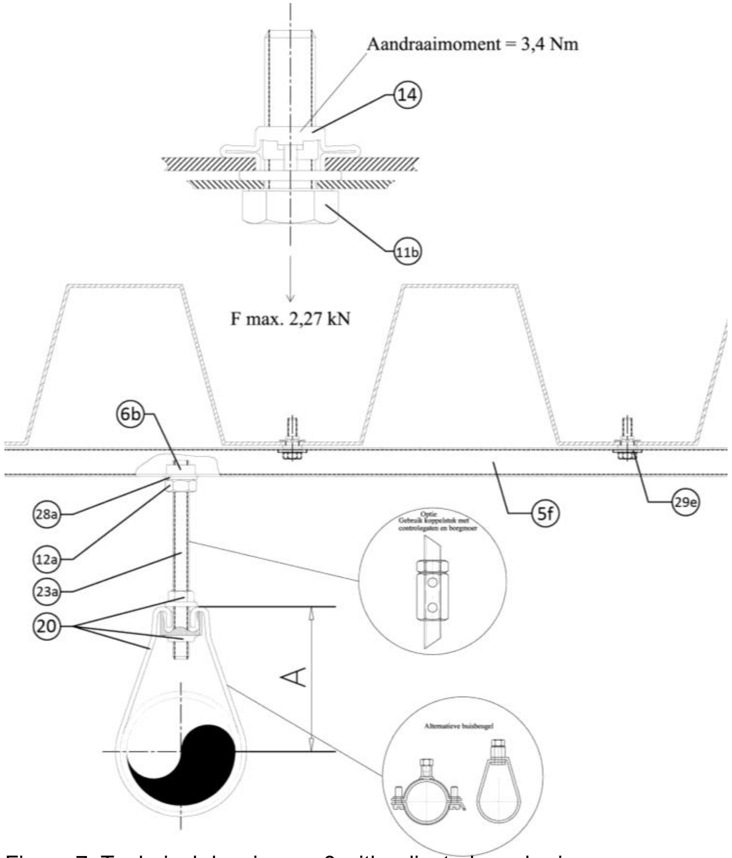


Figure 7: Technical drawing sss3 with adjusted numbering.

Integrated components: 23a
Separated components: 14,5f,6b,28a,12a,23a,20,11b,29e
(14 and 11, 6b and 12a are multiple components fulfilling a single function)

Nr.	Article number	Geometry	Article description	Function
14	8SJN	M6	Jack nut M6	Connecting channel to trapeze ceiling using bolt
5f	UNI20660	L=660mm	Channel UNI2	Servicing as supension area
6b	3910064	M10	Channel nut	connecting channel to threaded rod using Hex nut
28a	391301	M10 30mm	U-shaped washer	partitioning bolt from surface
12a	9345M10	M10	Hex nut DIN934	Connecting channel to threaded rod using Channel nut
23a	9755M10x1M	M10x1m	Threaded rod	Variably Partitioning hanger from channel using nuts Connecting hanger to channel
20	SUDN…	DN…	Sprinkler hanger	Supporting pipe by connecting to threaded rod
11b	93356x25	M6x25mm	Hex bolt DIN933	Connecting channel to trapeze ceiling using Jack nut
29e	90205M6	M6	Washer DIN9021	Partitioning surface from surface

Figure 8: Sss3 components with corresponding functions

Using these functions and the technical drawings a functional diagram could be formed. A functional diagram shows the functional relations between components and represents the systematization of a product. Therefore this diagram is very suitable to determine a components functional (in)dependence. Three levels can be discerned; subsystems, components and elements. This last level describes the elements which are needed to form a component. This was done because some components, for example a sprinkler hanger (20) contain multiple parts.

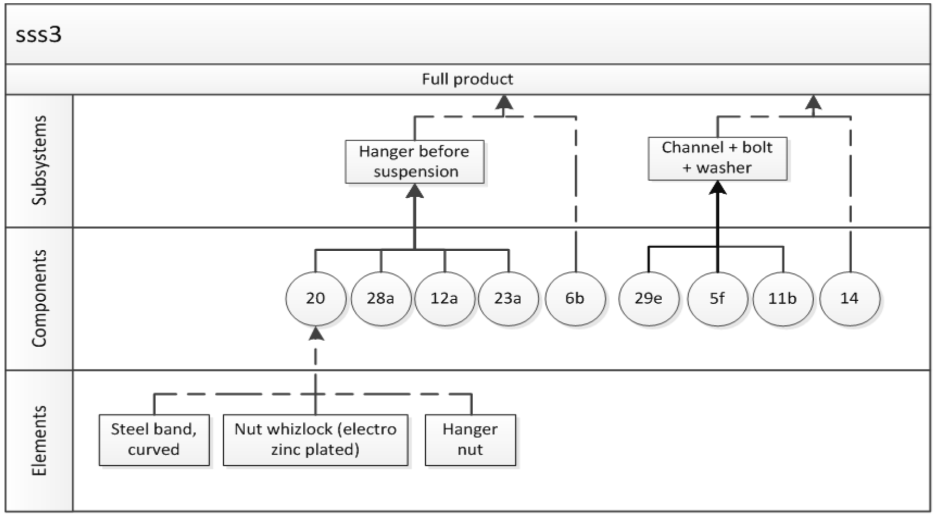


Figure 9: Functional diagram sss3

When multiple relations exist within a group of components and this group has no relations with other components it is called a subsystem. Two subsystems can be discerned in product sss3, which take up virtually all components. This type of functional structure means that these components are very suitable for merging. On a functional level, they all work together, and they have no functional connections to other components. Therefore, if there is no necessary order in which they can be assembled, these components are very suitable for merging. This would create more functional integration and would make the current flexible design a more fixed design.

Conclusions: All products have many components in subsystems. Also, virtually all components have merely one function, meaning that efficiency can be gained by merging components. This would create more functional integration instead of separation, resulting in an installation with fewer components. The components within subsystems should be the first on the list for merging, since they are already functionally linked.

5.4 Technical decomposition

A technical decomposition shows how components are technically linked and gives information about their relations and connections. A technical decomposition can be displayed as a relational diagram such as in figure 10. There are different types of relational structures; a layered assembly (resulting in a flexible structure), closed assembly (resulting in a fixed structure) and an open assembly.

Layered assembly is the stacking of components, meaning there is only one specific order in which components can be connected. In the relational diagram this is portrayed as a string of components connected by a vertical line. Layered assembly creates a flexible structure, meaning that the connection-chain can be interrupted at any point by removing only one relation.

Closed assembly is when components have so many relations that they become highly dependent on each other. This type of assembly results in a fixed structure which *seems* like a good thing in sprinkler supports, but since these closed assemblies contain multiple components it is less fortunate. This means that an installer needs to handle multiple components simultaneously when he wants to secure a connection. Not the most efficient method for installation.

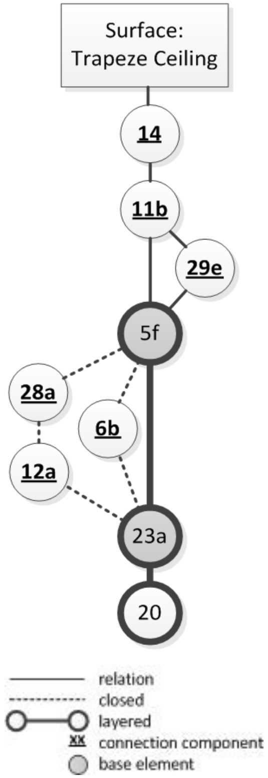


Figure 10: Relational diagram sss3

An open assembly occurs around base elements. A base element is a single element which connects multiple components without mutual relations. The resulting structure looks like a snowflake. Open assemblies have a lot to do with closed assemblies, seeing that the base element; the center of the snowflake, is often part of a closed assembly.

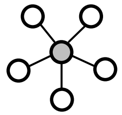


Figure 11: Snowflake structure

A base element could be a good point to start the redesign. Seeing that all connected components are non-related to each other, they do not have a fixed order in which they need to be assembled. This means that they can be permanently merged without any functionality being lost.

What the analysis of sss3 showed is that components 28a, 12a, 6b are part of a closed assembly. These components are all washers and nuts, all components used for connecting. This trend could be seen in the other products as well. Appendix D shows that virtually all nuts, bolts, anchors, rods and washers caused closed assembly, resulting in a relatively difficult installation for an installer because he needs to handle multiple components at the same time. What is interesting to note is that in the previous paragraph these same components came to light as being extremely functionally separated; needing to work together to fulfill one function.

Conclusions:

Virtually all non-connection components cause layered assembly.

Virtually all connection components cause closed assembly

Layered assembly and closed assembly are not suitable for sprinkler supports since they are most efficiently assembled with multiple installers, working at the same assembly simultaneously. These types of assembly therefore should be removed. This can happen by merging components. The base elements, often threaded rods and channels, can help in this. These elements could be a good start-up to permanently fix elements together.

5.5 Physical decomposition

As mentioned before, a technical decomposition consists of a life-cycle coordination, geometry of edges analyses and assembly sequence analyses.

- Life-cycle coordination

  A life-cycle coordination gives information about the time components can be used within an assembly. There are three limitations; a material's life span, its functional life span and a components need for adjustability. Since all current components are made from steel, there are no extreme values in material life span. A support's overall life span is estimated at about 60 years, with no exceptions to any of the components, corrosion being the main limiting factor. The functional life span however, is a lot shorter. When sections of a building are renovated or reallocated, a system's layout changes. When this happens, supports are destructively removed and new ones are hung in place. This is estimated to happen every 25 years to sections of a sprinkler system. This also happens when pipe sections need to be tested. This is also estimated to happen every 25 years.

  However, these two factors influence the entire support, and do not single out components. This means that the new design and the layout of its components does not have to take the life-cycle coordination into account.

  But, one limiting factor is still forgotten: the need for adjustability in components. This is not a real life span limitation, but rather a miniature life span limitation; seeing that all adjustments in the sprinkler supports are made on the first day of use. Some components such as the hanger need to be reshaped to fit the pipe, and height adjustments are sometimes made by pivoting components on the threaded rod.

  Conclusions: The factor of adjustability seems to be the only limiting factor to design a support on basis of life-cycle coordination.

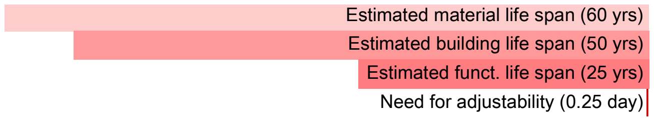


Figure 12: Life cycle limitations

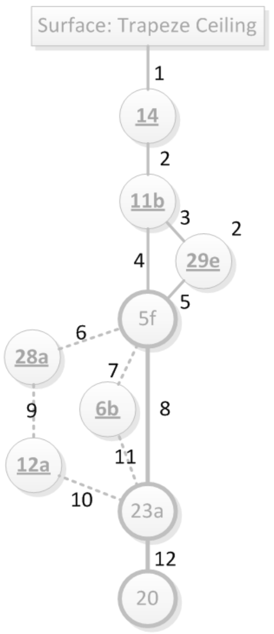


Figure 14: Connections with corresponding numbers

- Geometry of edges

A geometry analysis will show in which order components can be connected. There are 3 main types of geometry; an open geometry (results in flexible structures), overlapping geometry (results in relatively flexible structures) and closed geometry (fixed structures).

An open geometry has no specific order in disassembly. A component can be separated from another in at least 2 directions on opposite sites. An overlapping geometry results in a predetermined disassembly sequence. Therefore a component can only be removed in one direction. Such a type of geometry results in a relatively flexible structure, only the most center part of the assembly is hardest to reach. A closed assembly does not allow the removal of a certain component without removing another component first.

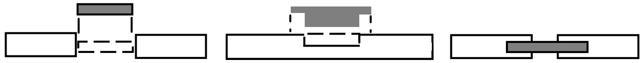


Figure 13: Open, overlapping and closed geometry

A list of all geometries of edges was made (figure 15). All connections between components were numbered (figure 14) and the corresponding connection type was added to the list. Also, the tools needed to secure or unsecure the connections were written down. To fully understand this list, it is convenient to look at the technical drawing in figure 7.

Nr.	Connecting components	Connection type	Mechanism	Tools
1	Jack nut (14)→Trapeze Ceiling	Closed	Reform materials	Drill, nut tool, cap screw, hex wrench, wrench
2	Bolt (11b)→Jack nut (14)	Overlapping	Screw thread	Wrench
3	Washer (29e) →Bolt (11b)	Overlapping	--	--
4	Bolt (11b)→ Channel (5f)	Overlapping	Pin + hole	--
5	Washer (29e) → Channel (5f)	Overlapping	--	--
6	U-shaped Washer (28a)→Channel (5f)	Overlapping	--	--
7	Channel Nut (6b)→ Channel (5f)	Closed	--	--
8	Threaded Rod (23a)→Channel (5f)	Open	Pin + hole	--
9	U-shaped Washer (28a) →Nut (12a)	Overlapping	--	--
10	Nut (12a)→Threaded Rod (23a)	Open	Screw thread	Wrench
11	Threaded Rod (23a) → Channel nut (6b)	Open	Screw thread	--
12	Hanger (20)→Threaded Rod (23a)	Overlapping	Screw thread	Wrench

Figure 15: Geometry of edges

Conclusions:

When looking at the geometry of edges in all the products (see appendix F, pages 28-33), it can be said that the designs are focused on flexibility; only a few of the connections are caused by closed geometry, the rest is either open or overlapping. Closed connections are more efficient for installers since they result in a *group* of components, which can be picked up simultaneously and be installed simultaneously. Closed geometries are therefore very suitable for pre-assembly. However, with these supports this is not the case. In current supports the closed connections are often between support and roof. This means that the *installer* has to secure them, instead of the supplier or Tyco. And he cannot do this in a pre-assembly whilst using lots of automation. No, he has to secure these connections standing on a scaffold or cherry picker, doing multiple and labor intensive actions such as drilling and anchoring. So the few closed geometries there are in current sprinkler supports, still cause inefficiency in installation.

- Assembly sequence analyses

An assembly sequence analysis combines the information from all other analyses. Many results are combined to form one diagram; an assembly sequence diagram. This diagram describes in a few steps, the entire assembly sequence of a product. Each step introduces components which can then be assembled onto the product. The goal while forming this diagram is to create as few steps as possible. This means that the assembly steps need to be combined as much as possible. When examining the diagram, this may seem illogical; steps are combined which cannot be combined in real life. However, this way of displaying the assembly steps shows the problem areas most clearly, and the most efficient way to add components to one another becomes clear. Figure 16 shows sss3's assembly sequence diagram.

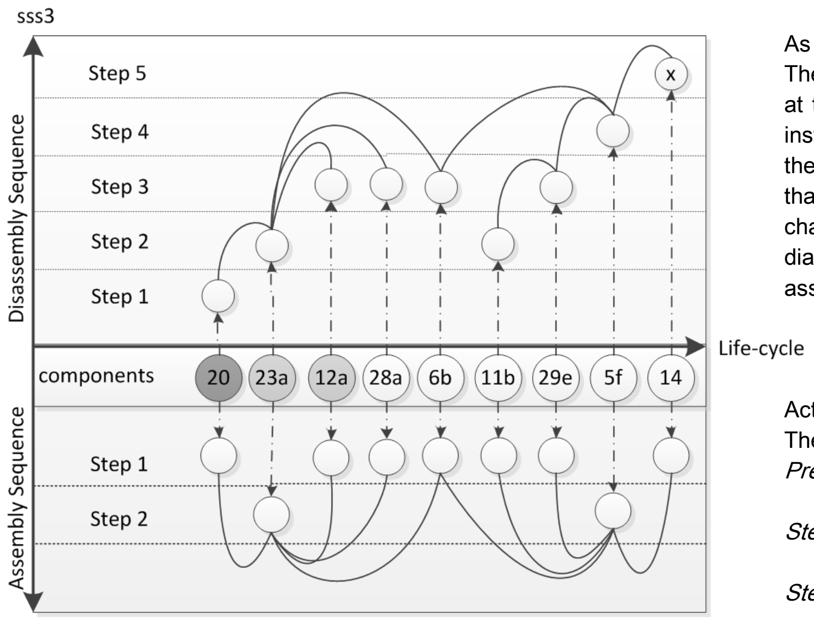


Figure 16: Assembly sequence diagram sss3

Vertically the different steps in (dis)assembly are shown. Horizontally the components in order of life-cycle are shown. In the case of sprinkler supports the only limitation in life-cycle was the adjustability, therefore the components hanger (20), threaded rod (23a) and nut (12a) are marked gray. They are put all the way to the left of the diagram since these components realize the height adjustments.
Two types of assembly can be recognized; gravity assembly and sequential assembly. Gravity assembly happens around base elements, it means that multiple components can be added to one element simultaneously. Sequential assembly is when components are connected on a predetermined order (also layered assembly in the technical decomposition).

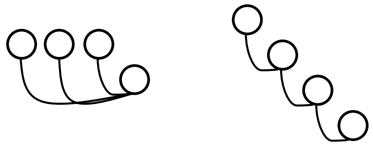


Figure 17: Gravity and sequential assembly

As can be seen in figure 16, sss3 needs a lot of gravity assembly. The base element (threaded rod), can be fitted with 5 components at the same time. In real life of course, this is impossible because installers only have 2 hands. But considering that the geometry of all these components requires the same motion; pivoting, it can be said that this can happen simultaneously. The same applies to the channel (component 5f). Appendix G, page 34-41 shows the diagrams for all other products. Also, the exact actions needed for assembly are described.

Actions within assembly:
The assembly sequence of sss3 is described as following:

Preparations:	Cut rod and channel in suitable lengths (they are delivered in lengths of 1 2 or 6 meters).
Step 1:	Install jack nuts, assemble components upon threaded rod and channel.
Step 2:	Connect threaded rod to channel and connect everything onto the jack nuts.
Finishing:	Place pipe and adjust height of hanger by pivoting components on threaded rod.

Conclusions:
There is a lot of gravity assembly, in all products but especially in sss14_2. Most of this gravity assembly is centered on base elements; connecting multiple connection components such as washers, nuts and bolts. Gravity assembly is only efficient when multiple installers are present or when machines can perform multiple tasks at the same time. The assembly sequences also showed that components with the shortest life-cycle are the first to be disassembled. This is a good sign since these components are then easy to reach when adjustments are needed.

5.6 Overall conclusions analyses

Efficiency can be gained by merging components. This is because of three reasons; most of the components are functionally separated, many are related in such a way that flexible structures are created and virtually all have geometries which allow (dis)assembly from multiple directions. These three criteria are not needed in sprinkler supports. Components with only one function cause flexibility and flexible structures are only efficient in installations with multiple installers. Disassembly from different directions is not needed, seeing that supports are only destructively removed. So, in order to create more efficiency in support installation, components can be merged. This creates multiple functioned mega-components which result in fixed structures. And there are possibilities. Components in subsystems are already functionally related. Components around base elements (often the same as the components in subsystems) do not have a predetermined assembly sequence. This gives the idea that these components, often connection components such as washers, bolts and nuts, can be merged without changing the overall functionality of a support.

How components are connected determines a structure's flexibility. As said before, a fixed structure is preferred in sprinkler supports. However, the current connections are of figure 18's categories VII, IV or II, resulting in a flexible structure. Therefore, the goal derived from these analyses is to upgrade most of these connections to a category I, creating a fixed structure. Of course, while doing this, the life-cycle coordination has to be kept in mind; components adjusting height cannot be chemically connected.

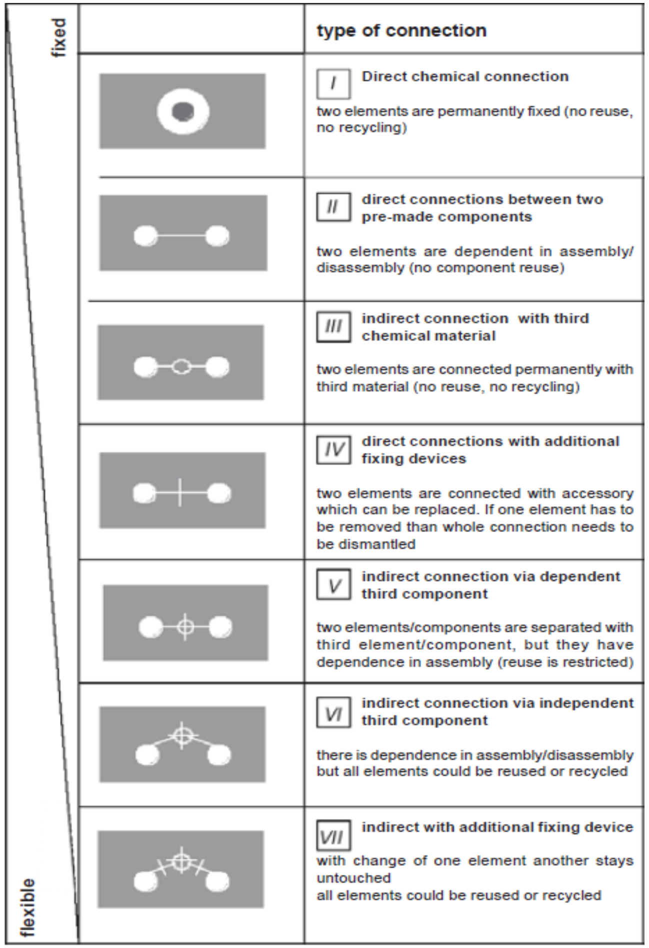


Figure 18: Methods for connecting in order of flexibility

Ch.6

Time aspect

Chapter 4.3 concluded that an ideal sprinkler support is a compact product, suitable for many diameters, many heights and made up of few components. Also, the functional and technical decomposition concluded that the analyzed products have too many components to be efficient in installation. Most problems are caused by connection components such as washers, nuts and bolts.
To reach the goal of this assignment however, not yet enough information is gathered. The money and time aspects are still left unanalyzed. This chapter will look at the time aspect of installation.

To retrieve accurate information, desk research was done. During interviews, customers were also asked about the time spend during installation, but this proved difficult information to retrieve. Management around installations often uses standard time values when evaluating projects, using data sheets instead of stopwatches. These same data sheets were used for this assignment. Luckin's Time Guide[18] and Gustav's Ende Norm[19] for example. These norms list time data about the installation of all HVAC, electrical and other installation systems. They contain lists with average time values for grooving pipes, hanging supports, checking systems, etc. The time it takes to install 1 sprinkler support however, is not described. Instead, the norms state how long it takes to install one sprinkler head. With this information; the time it takes to install one support is derived.
The norms state that an average installation of 1 sprinkler head takes 100 minutes. However, this number is composed using the overall costs for a project, including transport, worker holidays, administrative preparations etc. To remove these factors from the time measurements a diagram is made. This diagram states the *proportional* time spent on the installation of 1 sprinkler head.

The percentages in this diagram were derived from Luckin's Time Guide and Gustav's Ende norm. Subsequently, customers were asked how long the actual installation of 1 sprinkler head takes, these percentages can be converted to time values. It turns out that 25 % of the time on the installation site is spent installing sprinkler supports. Customers indicated that the effective time spent on the installation of 1 sprinkler head is around 25 minutes, of which 7 to 8 minutes is spent on installing supports. Looking at the diagram this data corresponds; 25% of 25 minutes is roughly 7 minutes.
Since the data from the customers seems to be correct, and 1 sprinkler head requires the use of 1 support[27], it can be said that it takes 7 minutes to install one sprinkler support. Within this 25 minutes however, the work done outside the installation site was excluded. Therefore actions such as pre-assembling at the installation company were left out. This means that the actual installation time for 1 sprinkler support could be even more than 7 minutes.

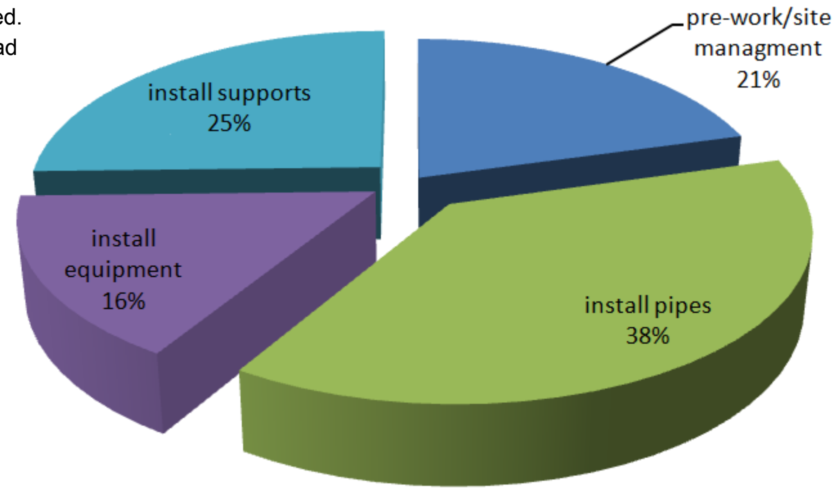


Figure 19: Time consumed on an installation site

Ch.7

Money aspect

To form a complete schedule of requirements, information is needed about the money aspect if installation. To create a comparable overview the most common support is considered; this support is hung from a concrete slab, consists of a non-drill anchor, threaded rod (of average length: 100 mm) and double bolted pipe clip. This support will be most often used to support pipes with nominal diameter DN65. Common variations on this support are supports with hangers or beamclamps instead of the pipe clips.
The purchasing costs for these supports are displayed in figure 20.

Type of support (for DN65)	Tyco (€)	Customer (€)
Pipe clip + anchor + 10 cm rod	0.46	4.44
Hanger + anchor + 10 cm rod	0.63	3.54
Pipeclip + Beamclamp + 15 cm rod	0.74	6.39

Figure 20: Purchasing costs common supports

Figure 21 shows the cost division for a 100.000 euro project. The duration costs are plotted against the purchasing costs. On average; 10% of the costs of a project are for organization, 65% for purchasing and 25% for the duration of the project (hiring crew, renting space, keeping installation site empty etc).
Using Tyco's confidential data some tasks in installation were plotted. Displayed is how much money is spent buying the materials and the corresponding duration costs for these tasks.
The steepness of the diagonal line represents the overall purchasing costs divided by the overall duration costs. This line could be considered as the most efficient ratio between purchasing costs and duration costs in a current average project. However, none of the tasks are actually *on* the diagonal line. The pipes and equipment are above it, meaning they are relatively expensive to purchase, but take up a 'small' amount of time to install. As can be seen, the supports are below the line, meaning they are relatively cheap to buy, but lose that lucrative potential because they take up a relatively long time to install.

It is a deficient diagram since it does not take into account the precision in which tasks need to be performed. However, it could be the argument to create more expensive, faster to install supports. Because, time is money, and the current supports are often bought only looking at the purchasing prices, which are low. The fact that these cheap supports take up a lot of time to install is overlooked. This makes the current supports inefficient in installation.

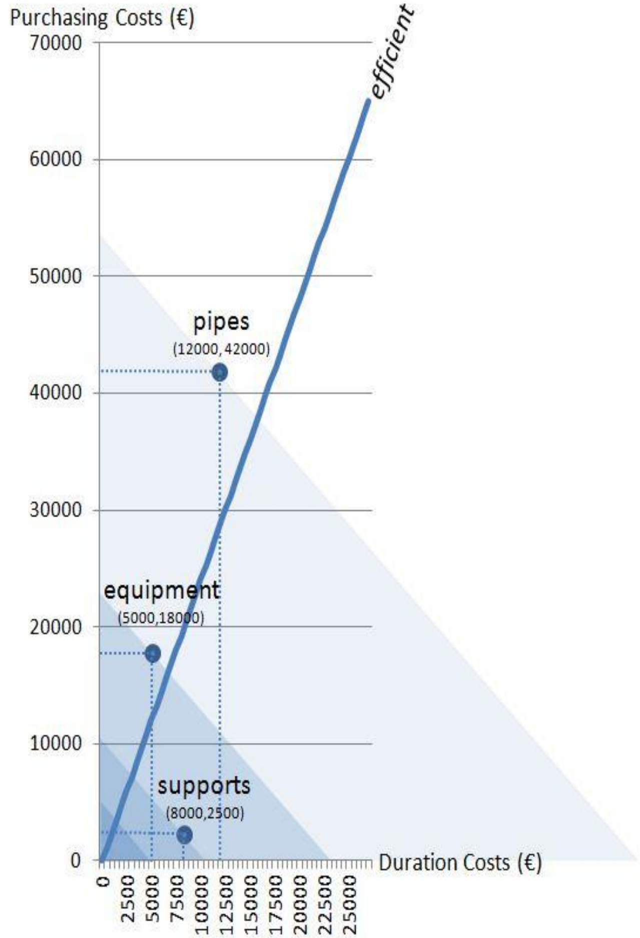


Figure 21: Costs around installation

Ch.8

Additional iformation

To form a schedule for requirements, some additional information was needed. This information was gathered from customer interviews, Tyco employees, Wopf employees (main supplier) and desk research. The conclusions drawn are shown behind the arrows.

8.1 Support design

- The most commonly sold support has a non drill anchor, threaded rod and double bolted pipe clip (figure 23, left), giving a total of 6 components. However, the most offered support by Tyco has a pipe hanger instead of a pipe clip (figure 23, left), resulting in a product with 5 components. The pipe clip variant cannot be adjusted in height after the rod length is cut. For this reason; pipe supports shall not have more than 5 loose components.

- Clips and hangers are made from steel bands. There is a minimum required thickness of these bands. A USP hanger for a pipe DN25 requires a 12x1,5 mm steel band for example, a USP hanger for pipe DN50 requires this as well. So the relation between band sizes and pipe sizes is not linear. Instead, groups of pipes require the same band thickness. The groups are; Pipes of DN 25, 32, 40 and 50 mm, DN 65, 80, 100 mm, DN 125, 150 mm and DN 200, 250 mm. For this reason; one support suitable for all pipe sizes is desirable because it would require fewer changeovers in the production machinery and would ease the ordering of supports.

- Sprinkler piping and supports are made out of (processed) steel, this is done because it is cheap, strong and prevents galvanic corrosion. For this reason; steel will preferably be used in the new designs. Otherwise, extra costs will be made looking for new suppliers and buying more expensive materials.

- To ensure the quality of the supports, approvals are met. In case of sprinkler supports, the most commonly applied approval is that of FM. For this reason; the FM approvals for sprinkler supports will be inserted into the schedule of requirements

Article number	D Inch	DN	G	H mm	H1 mm	FM	VdS	KG 100 pcs.		RFQ
USP15	01-Feb	15	M8	56	41		Y	9.4	50	
USP20	03-Apr	20	M8	57	42		Y	4.8	50	
USP2010	03-Apr	20	M10	57	42		Y	4.8	50	
USP25	1	25	M8	57	42		Y	5.2	50	
USP2510	1	25	M10	57	42	Y	Y	5.2	50	
USP32	1 1/4	32	M8	57	42		Y	5.6	50	
USP3210	1 1/4	32	M10	57	42	Y	Y	5.6	50	
USP40	1 1/2	40	M8	62	47		Y	6	50	
USP4010	1 1/2	40	M10	62	47	Y	Y	6	50	
USP50	2	50	M8	72	57		Y	6.4	50	
USP5010	2	50	M10	72	57	Y	Y	6.4	50	
USP65	2 1/2	65	M10	89	69	Y	Y	13	25	
USP80	3	80	M10	104	84	Y	Y	14	25	
USP100	4	100	M10	135	115	Y	Y	16	25	
USP125	5	125	M12	151	129	Y	Y	20	25	
USP150	6	150	M12	188	166	Y	Y	22	25	
USP200	8	200	M16	236	214	Y	Y	46	10	
USP250	10	250	M20	310	288		Y	80	1	

not suitable for sprinkler piping
group 1
group 2
group 3
group 4

Figure 22: Grouping in supports

Figure 23: Left: double bolted pipe clip. Right: USP hanger.

8.2 Transport

- The costs of transport are measured in packaged volume and weight. How much that is for the current supports is still unknown and could be something for the successor of this assignment to find out. However, when components are packaged separately, they take up more volume than a fully assembled support. For this reason; the aim is to pre-assembly early on. This would result in less transported volume and more chance for automation.

8.3 Installation

When asking the customer project leaders about their methods for installing supports the following things became clear.

- Flexible armovers are often used. In contrast to rigid armovers, these flexible tubes running between pipes and sprinkler heads make it possible for pipes to hang at any location between a suspended ceiling and roof. The use of flexible armovers is handy for installation, since the horizontalness of pipes is then negligible. Subsequently, the current method for support installation is not hindered. In this current process rods are cut by hand, often one rod at a time. This is an inaccurate process and therefore the height of a pipe can vary, sometimes 0.5 till 1.5 cm. These inaccuracies result in the removal and reinstallation of 2% of the installed supports. Flexible armovers make these inaccuracies in a support unimportant, since sprinkler heads can still be installed at any preferred height, no matter how high the pipes hang. For this reason; the possibility of height adjustments is not a great priority for the support concepts.

- After the pre-engineering plans are made final, some installers may choose to lay pipes to their own vision, messing with the plans and causing pipes of the sprinkler system to be hung in another height than specified in the plans. This rarely happens, but it can occur. For this reason; the new support concepts must allow pipes to hang at more than one distance from the roof.

- Support hangers are reformed or screwed open to fit onto the pipe. This is because supports cannot be slid onto the pipes since this will damage the protective paint coat on the pipe, another reason for this is that pipes are too heavy to realize an sliding action. For these reasons; the pipes can be assembled quickly onto the new supports without damaging the paint coat.

- The current installation requires the following tools: a rod cutter, anchor setting tool and drill with several attachments, For this reason; the new support installation will require no more than 2 mechanical or automated tools.

- Simultaneously installing multiple supports on one pipe section is logistically impossible. For this reason, an ideal support will be one which can singularly hold up a pipe while other steps for assembly are taken.

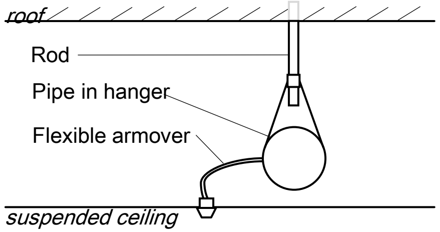


Figure 24: Use of flexible armover between foundation roof and suspended ceiling.

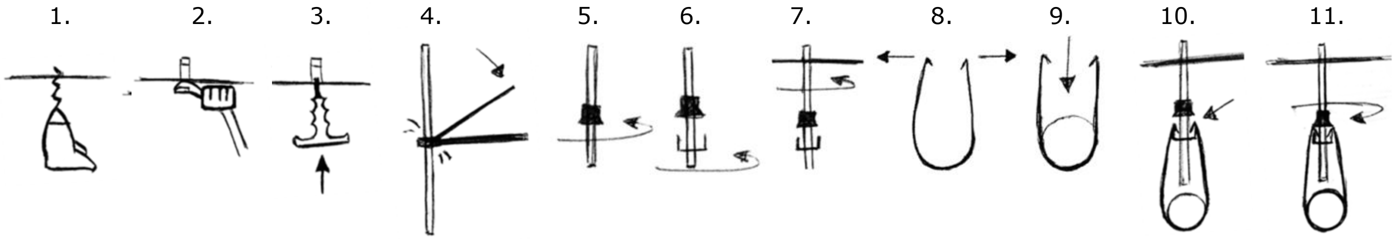


Figure 25: Assembly steps of a USP-hanger being mounted onto a concrete slab

Ch.9

Schedule of requirements

With the information in previous chapters a schedule of requirements could be formed. This list of demands and wishes would aid in the making of concepts and in testing their functionality. The national, continental and global approvals[20-30] were also consulted; these are the legally set minimum requirements for the installation, design and testing of sprinkler supports. A selection of these approvals was stated as hard demands since they have to be met in order for Tyco or the supplier to sell the products.

9.1 Demands (approvals)

- Supports shall completely surround the pipe
- Supports shall be of the adjustable type in order to secure an even load-bearing capacity.
- Connections shall be secured
- The used materials shall be non-flammable. Hanger components shall be ferrous.
- Hangers shall be designed to support an accidental load of 5 times a water filled pipe plus 114 kg extra weight. The table below shows these loads for the corresponding diameters of steel piping.
- Width hanger: The width of a hanger should be able to contain pipes with DN 25, 32, 40, 50, 65, 80, 100, 125, 150, 200 or 250 mm
- Height support:The height of the support should be such that the centerline of the sprinkler's thermal sensing element is a min. of 25mm and a max. of 300mm vertically below the underside of the ceiling. Desired is a min of 75 and a max of 150 mm
- Height adjustments: hangers should allow a rod to pass through a screw thread for at least 2 cm
- The normal and shear forces (shocks) will be absorbed by the shape of the support.
- The load bearing capacity of the supports should not deteriorate more than 25% when the material is heated above 200 degrees Celcius.
- Supports which are reshaped during the assembly (such as partial hangers), for example by strong adjustments from screws, knife-edge seals or sharp edges, will be limited for the use of pipes d $\leq$ 65mm.
- Force-fitted pipe to hanger connections are not allowed.
- Beamclamps for pipes >65mm need a securing element to prevent sliding in a lateral direction.
- The table below, concerning loads and geometry, must apply for the entire support.

Diameter		Length pipe		Weight water filled pipe		Load
mm	inch	m	foot	(lbs/ft)	kg	N
25	1	2,1	6,89	2,54	7,9378665	1508
32	1,3	2,1	6,89	3,56	23,363579	1665
40	1,5	2,7	8,86	4,4	47,734347	1986
50	2	3	9,84	6,3	84,378896	2498
65	2,5	3,4	11,2	9,49	163,25813	3474
80	3	3,7	12,1	13,11	267,08956	4660
100	4	4,3	14,1	19,96	549,22238	7384
125	5	4,9	16,1	28,65	1023,6879	11366
150	6	5,2	17,1	39,86	1603,9645	16249
200	8	5,8	19	63,2	3163,908	27876
250	10	6,1	20	95,84	5307,0998	43793

Nominal pipe Diameter	Min. nominal load capacity at 20 ℃	Min. ultimate load	Min. thread	Min. length of anchor bolt	Min. cross section
mm	kg	kg	--	mm	mm^2
Pipe d < 50	200	400	M8	30	18
Pipe d=50-100	350	700	M10	40	33
Pipe d=100-150	500	1000	M12	40	33
Pipe d=150-200	850	1700	M16	50	50
Pipe d=200-250	1000	2000	M20		60

9.2 Wishes

GEOMETRY wishes

- Width hanger: 4 different hanger designs can support sprinkler pipes with Nominal Diameters from 25 till 250. Hanger 1 shall support DN's 25, 32, 40, 50, second Hanger: 65, 80, 100. Third Hanger: 125, 150, Fourth Hanger: 200, 250
- Height hanger: Adjustments can be made with an accuracy of 7 mm within a range of 75-300mm
- Replacement of current most common support shall have no more components than 5.
- Product installation requires no clean-up of rest-materials or chippings.
- Installation requires no more than 2 mechanical or automated tools.
- Product allows sliding pipe within hanger during installation.
- Has to be recognizable as an adequate, capable, efficient and safe sprinkler support (component)
- Geometry has to be designed for intuitive installation.
- Can replace clearly defined section of current sprinkler support(s) so that using it in combination with other products stays a possibility

LABOR wishes

- Need for customers to see the installation area before choosing what supports to use is removed
- Assembly does not have to happen on the installation site. (can be fully assembled by Supplier or Tyco)
- Installation of supports and suspension of pipes can be done by one person
- Components must have multiple functions (singular functioned components such as bolts/washers/nuts are not used)
- Adjusting pipe height and securing the adjustment can be realized by a single component
- Need for adjusting pipes in height is removed
- Need for replacing pipes for testing is removed

TIME wishes

- Only one order needs to be placed for a customer to receive the new product.
- To send the product to the customer may take no longer than 48 hours
- Preparations for installation of 1 hanger at installation company should take no longer than 0 min.
- Preparations for installation of 1 hanger on construction site should take no longer than 1 min.
- Effective installation time (hands on tool time) of 1 support should be no longer than 7 minutes.
- To accurately suspend 1 pipe section takes up no more than 30 seconds.
- Installation of 1 support leaves no more residue behind which can't be cleaned up within 1 min
- Product lifespan can equal or surpass the functional lifespan of a building (70 years).

MONEY wishes

- Redesign of commonly used offered support may cost no more than: 3.54 euro for the customer
- Redesign of commonly used support may cost no more than: 0.63 euro for Tyco
- Redesigned product requires no new tools to be purchased

(specification for successor)

- Transport: product is no heavier than.. kg and has a
- Transport: components together have a minimum package volume of.. m^3
- Production: techniques shall suffice in areas of expense, speed, quality, quantity
- Production: materials used are of lucrative kind and must functionally suffice.

Ch.10

Morphological schedule

The list of requirements in previous chapter was the input for the forming of concepts. The wish; 'Concepts must have multiple functions' was important (see chapter 5.6 for motivation) since this wish influences a lot of the other wishes as well ('a support shall have no more than 5 components', 'placing one order means receiving a full product', 'the new product shall have less transported volume', etc.).

When looking at this wish, an ideal outcome would be a one-component support. This could be realized by merging all components. However, since the possibility of adjusting a pipe's height should remain (see chapter 8.3), and since installation companies like the option of replacing components in their assortment with other support components (see chapter 3.3), it is impossible to create a one component support. It would not sell.

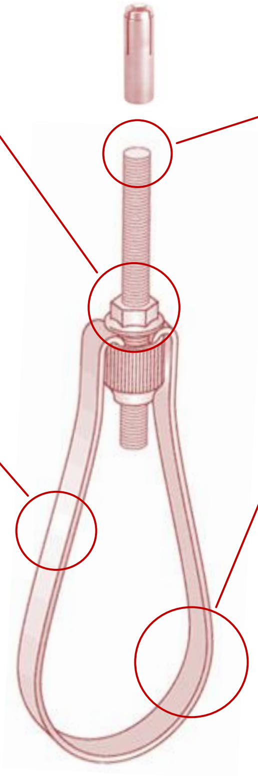
For this reason, not all components were merged. Instead, only sections were chosen for redesign because these sections cause significant problems in installation efficiency. The corresponding problems can be read below. The estimation is that if all these problems are solved, almost the entire schedule of requirements will be met. Page 24 shows the solutions in a morphological schedule and appendix H describes the underlying thought processes.

Main problem:

- Too much components

Other problems:

- Securing nut only has one function
- Adding pipes to hangers takes up too much time and labor
- Cutting and pivoting on rod is time and labor consuming
- Too much different sized hangers



Securing the pipe.

The securing nut prevents the pipe from falling down whenever vibrations within the system cause the pipe to move upwards in the support. This happens on rare occasions. Problem: the securing nut is a single-functioned component which is inefficient in ordering and assembly (see chapter 4.1 and 5.6).

Height of pipe

The length of the rod determines the height of the pipe. Rods are mostly cut individually and components with thread are pivoted on. Problem: cutting and pivoting rods is labor and time consuming (see chapter 4 and 8.3).

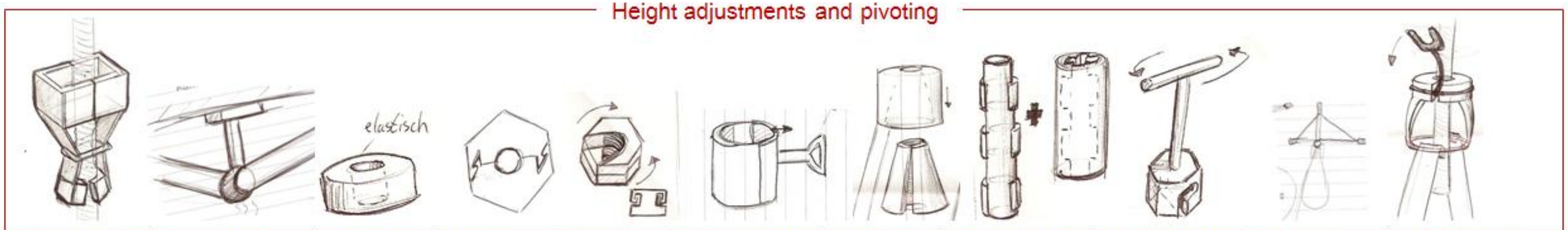
Hanging the pipe.

Pipe surrounding components (hangers or pipe clips) often need reforming or a lot of components to hold a pipe, which is often heavy (see chapter 8.1 and 9.1). Problem: adding heavy piping to multi-component hangers takes up too much time and strength.

Width of pipe

For production reasons it is more efficient to have one support for multiple pipe diameters (see chapter 4). Problem: every pipe size requires a corresponding hanger size. There is no uniformity.

Height adjustments and pivoting

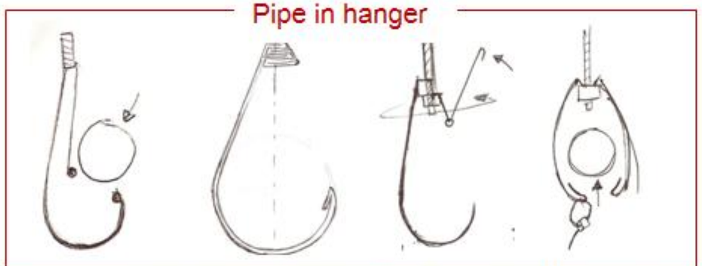


Moment caused by pipe causes clamping on rod	Variable angle prevents need for height adjustment	Elastic nut prevents need for pivoting	'click' nut prevents need for pivoting	'turn' nut prevents need for pivoting	Pivoting motion, causes clamping on rod	Downwards force causes clamping by cone	Upwards motion plus quarter turn determines height.	Upwards motion plus quarter turn determines height.	Object has standard lengths which can all be used	Tool-box-clamp handle clamps wire on rod and secures connection

Securing pipe in support

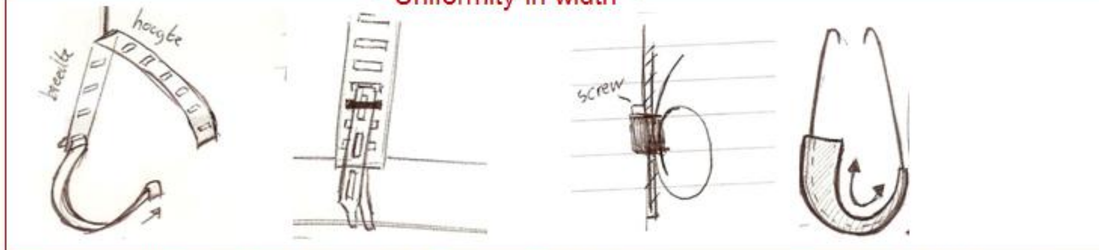
Pipe orientation secures connection: rod	Anchor setting tool permanently secures height of hanger basket	Click connection with flap at the bottom secures height	Addition to hanger prevents upwards motions after pipe is hung	Standard length rod clamps to roof, variable length hanger.	Pipe orientation secures connection: hanger	Secures height and prevents upwards motions	Pipe orientation secures connection: 2-side hook on beam

Pipe in hanger

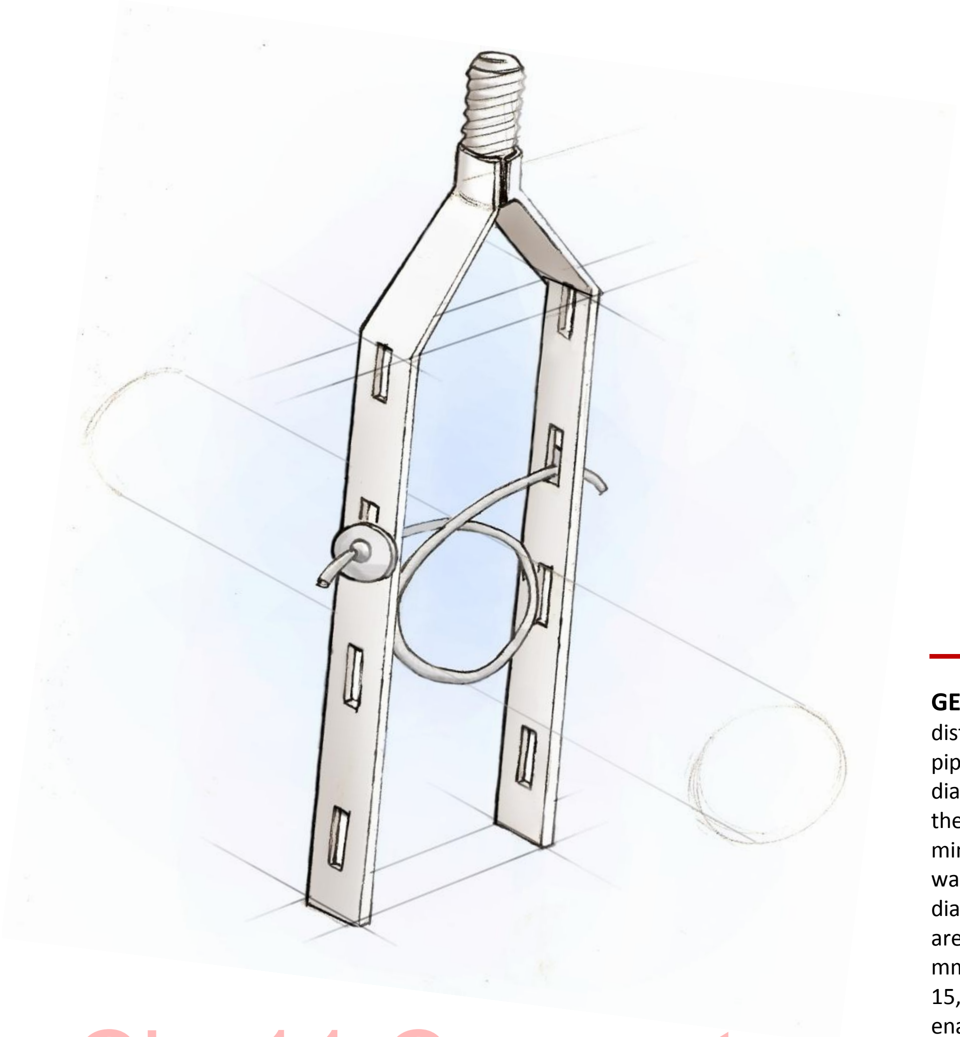


Pipe presses connection shut, no securing step needed	Hanger with thread. Bar is needed to open up the hanger	Pivoting bar. Pipe orientation closes hanger	Hanger clamps pipe, Hanger is closed at bottom

Uniformity in width



Standard length Rod-extension determines height and width.	Wire surrounds pipe. 2 strips (plus anchor) determines the height and width	Snake clamp implemented in hanger regulates the diameter	Flexible triangular add on can slide in hanger; determining the hanger diameter



Concept 1

UNIQUE SELLING POINTS This 2 component support can hold pipes of multiple diameters at multiple heights. Since the holes in the steel band are in fixed positions, there is no need for small height adjustments. Steel wire is used (which is not popular amongst installers because of its unstable appearance), but the steel bands create more (visual) stability.

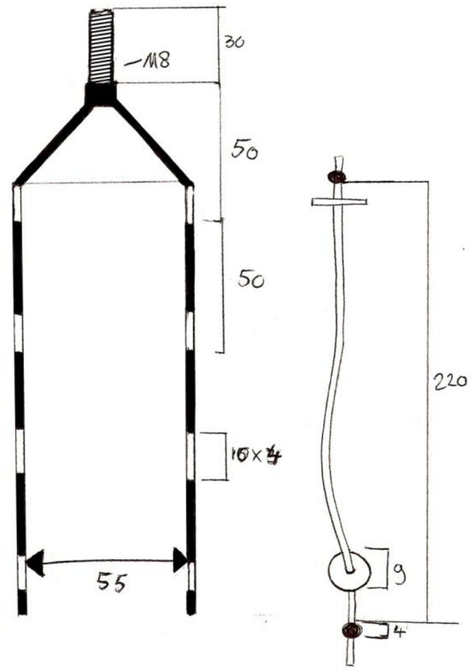
OVERALL ADVANTAGES

- Suitable for multiple pipe widths and heights
- No height adjustments necessary
- No rods have to be cut
- Only 2 components
- Easy to order
- No tools needed except for anchor setting

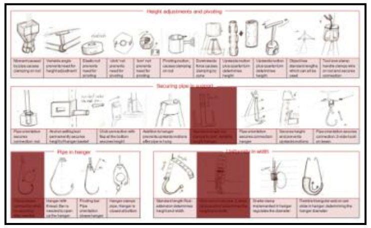
OVERALL DISADVANTAGES

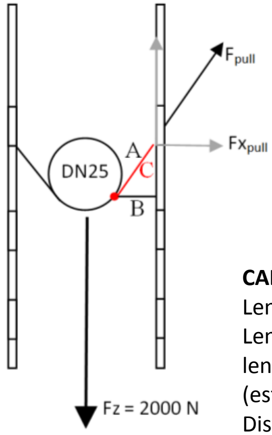
- Appearance varies from current supports
- Material loss by double bands
- Pipe needs to be held up during assembly
- Bends, holes, and welds reduce strength
- Bands may hang in the way of other systems

GEOMETRY A steel wire, 230 mm long (70mm for the distance, 190 mm to surround the pipe), can support pipe sizes from 25, 32, 40 and 50mm nominal diameter. These sizes were picked since they require the same width in hanger. These pipe sizes require a minimum of M8 for the threaded upper part. The washers attached to the wire are 9 to 10 mm in diameter; small enough to fit through the holes, and are kept on the wire by welded knots no larger than 4 mm. The holes in the steel band are distanced 5, 10, 15, 20 cm from the ceiling and are 10x4 mm. This enables the pipes to hang up to 25 cm from the roof; not reaching the maximum allowed distance of 30 cm. The minimum cross section of the steel bands is larger than 18 mm^2 as stated by the approvals. Larger, because extra material is needed around the holes, where local stresses are higher.



MORPHOLIGICAL SCHEDULE This concept's main thing is to corporate multiple widths into one support. Also, the problems with height adjustments (cutting rod and pivoting) are solved by presenting only 4 heights in which the pipe sections can hang. Using this method, no height adjustments are needed after the pipe is hung, since no inaccuracies can occur by cutting the rods. The solutions presented here cannot be found in the morphological schedule. A solution which can be found in the schedule is the implementation of multiple pipe width. Using a strip with holes and an 'anchor' a pipe is secured in place by the gravitational forces on the pipe.



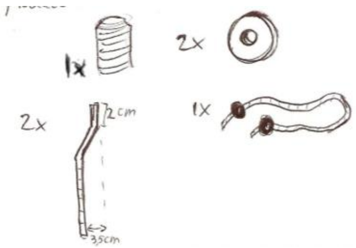


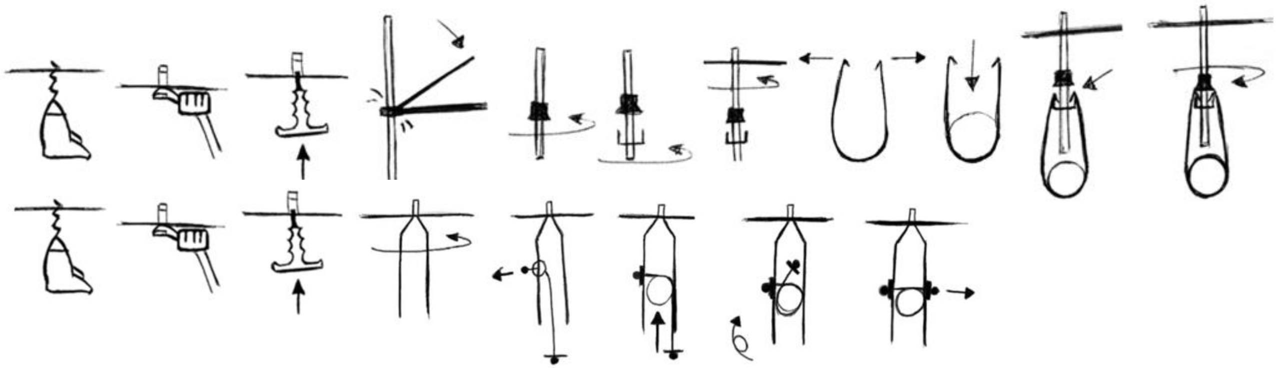
CALCULATIONS

Length wire around pipe = 30*Pi = 94 mm
Length wire not around pipe = 230-94 = 136 mm
length wire within bands = 136-16 = 120
(estimated is that the red dot is on 0.75pi radians)
Distance A = = 120/2-94*1/8= 48 mm
Distance B = 0.5*55-cos(0.75pi)*15 = 38 mm
sin Angle C = B/A = 38/48
=> Angle C ≈ 52 degrees
=> $Fx_{pull} \approx 2000/2 * \sin(52) \approx 790$ N

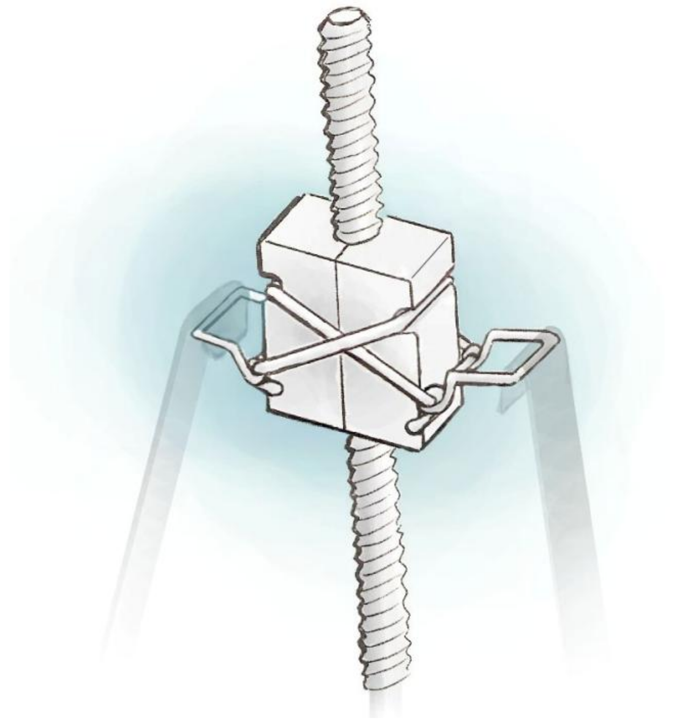
This means that the pulling force at the bands with a maximum nominal load of 200 kg is about 790 N at each side. This is large, so there is a high chance that the pipe will pull the steel bands together when it is maximally loaded.

PRODUCTION A piece of rod needs to be threaded at the top, and welded to two pieces of steel band at the bottom. These steel bands need 4 holes to be punched into them, they need to be reformed into a circular shape at the top and bent 2 times at 50 degrees in opposite directions. A steel wire needs to be fitted with 2 washers and needs to be thickened with weld knots at both end of the wire. When all these steps are undertaken, there are 2 components left for the customer to handle.



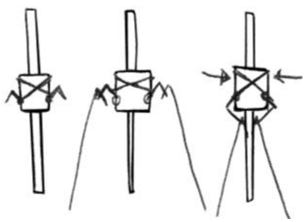


ASSEMBLY SEQUENCE This concept shortens the assembly sequence by three steps. However, the adding of the pipe is more labor intensive; it requires the heavy pipes to be held up whilst fixing the steel cable. (see figure on the right).



Concept 2

UNIQUE SELLING POINTS This concept prevents the need to pivot on a rod. The 2 halves of this product contain swing stoppers. This means that when the levers are up, there is room in between the blocks for the product to slide onto the threaded rod. When the levers are pulled down by the weight of the hanger, the grip around the rod tightens. This secures the position on the rod, and also, it secures the hanger against the bottom of the product. In short, one motion secures all connections.



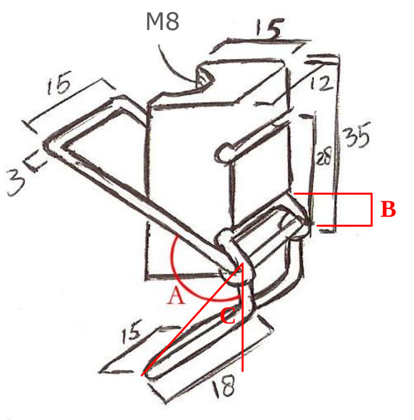
OVERALL ADVANTAGES

- Few installation steps
- Few components
- One motion secures all connections
- No tools needed except for anchor setting
- No pivoting required

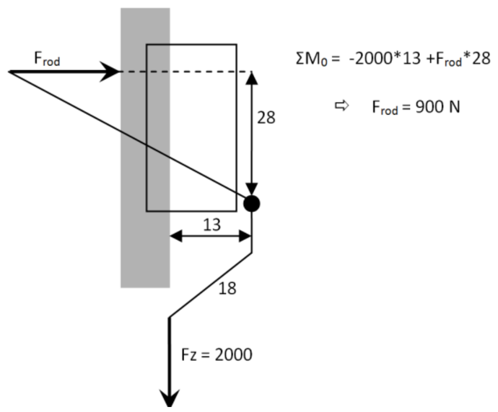
OVERALL DISADVANTAGES

- difficult to produce
- Hanger might tend to bend back, opening the product

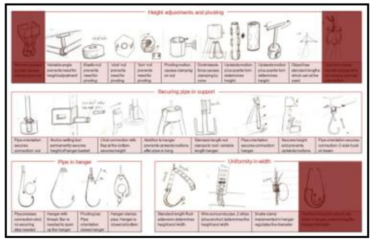
GEOMETRY The product consists of halves, each threaded M8 on the inside of the slightly oval hole (oval, to optimize sliding capacity). Making it suitable for piping until DN50.
The swing stopper mechanism tightens the two halves together, meaning that angle A needs to be smaller than 180 degrees when the levers are down, and that section B must be at least 3 mm to allow the blocks to be opened up sufficiently. Angle C must not be too large, since gravity will then counteract the will of the levers to stay down. This results that the lower part of the levers is 18 mm The width is 15 mm, large enough to fit 12 mm hangers. The distance from the bottom of section B towards the upper end of the mini-rod is 28. Not too large since this will interfere with angle A.



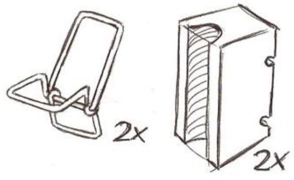
Quick calculations show that at a maximum nominal load of 200 kg the clamping force on the rod will be roughly 900 N from one side. This will be more uniformly spread by the block.

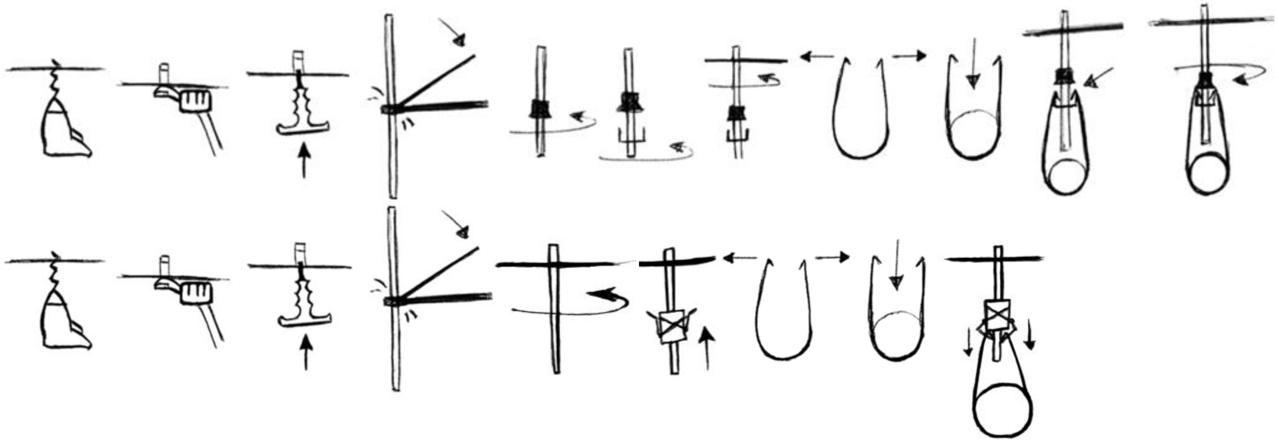


MORPHOLIGICAL SCHEDULE Only a few aspects of the morphological schedule (chapter 10) are shown in this concept. The solutions for changing height and pivoting are most important and can be seen clearly. No solutions for securing are implemented, since this concept has this feature already, so no extra solution is needed. When looking at the hanger type, the current one can and must be used. Another type would interfere with the pulling action which secures all connections.

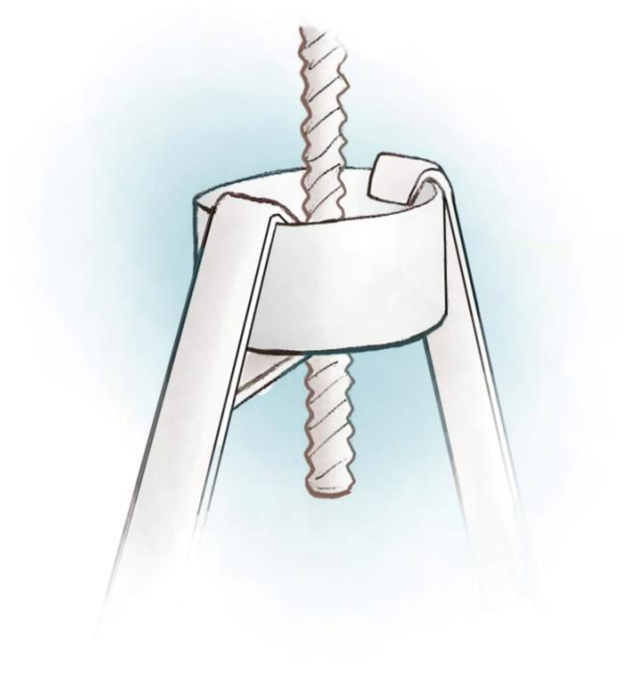


PRODUCTION Two steel blocks of 15x12x35 mm have to be edited. The half cylinder hole need to be drilled and threaded (M8). The outside of the blocks must be fitted with two horizontally cylinder holes. The rod structures can then be fitted, keeping the product halves together. The production of these structures is similar to that of any swing stopper (see figure on the right).
Another production route may be to create the product from one whole block of steel, which is sequentially cut into two halves.





ASSEMBLY SEQUENCE The figure on the left represents the assembly sequences of the current support and that of concept 2. The first three actions of anchor setting are equal, but the sequence of concept 2 is shorter. The difference lies in the pivoting. Concept 2 requires only one pivoting motion; that of the rod in the anchor.



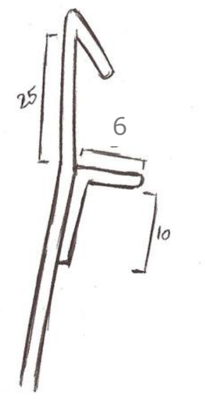
OVERALL ADVANTAGES

- Fewer installation steps
- Few components used
- Only simple adjustments to current component
- No extra tools needed

OVERALL DISADVANTAGES

- Extra production step needed
- Chances of damaging the pipe wile increase

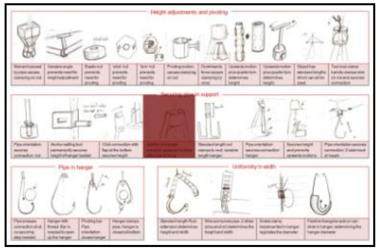
GEOMETRY An extra piece of steel band is added to the current hanger, this piece is bent in the middle at an angle of 90 degrees and approximately 16 mm long. 10 mm to fix it to the steel band of the hanger with a point weld and 6 mm wide to 'clamp' the hanger under the basket. This extension should not be longer than 6 mm (half the diameter of the basket minus 5 mm), or else it will clamp against the rod. The distance to the top will be around 25 mm, enough to easily assemble the hanger, but not more, since the hanger will not be secured if it is placed further down.



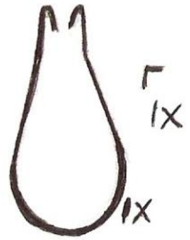
Concept 3

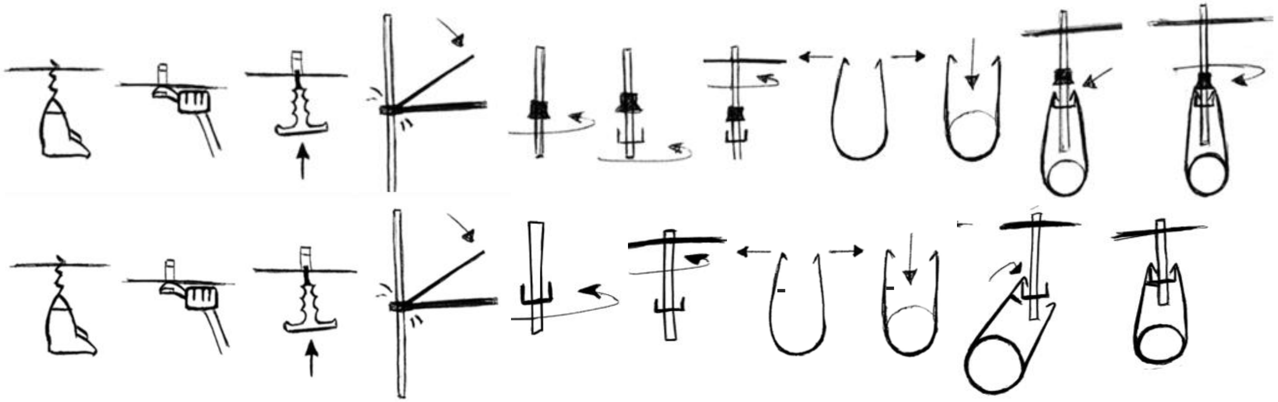
UNIQUE SELLING POINTS This concept prevents upwards motions of the hangers after a pipe is suspended. It removes the need for a securing nut

MORPHOLOGICAL SCHEDULE This concept only focuses on the securing element. It is not an easier way to change the height of the hanger, nor an easy way to assemble the hanger. It is a subtle change which makes the securing nut redundant.



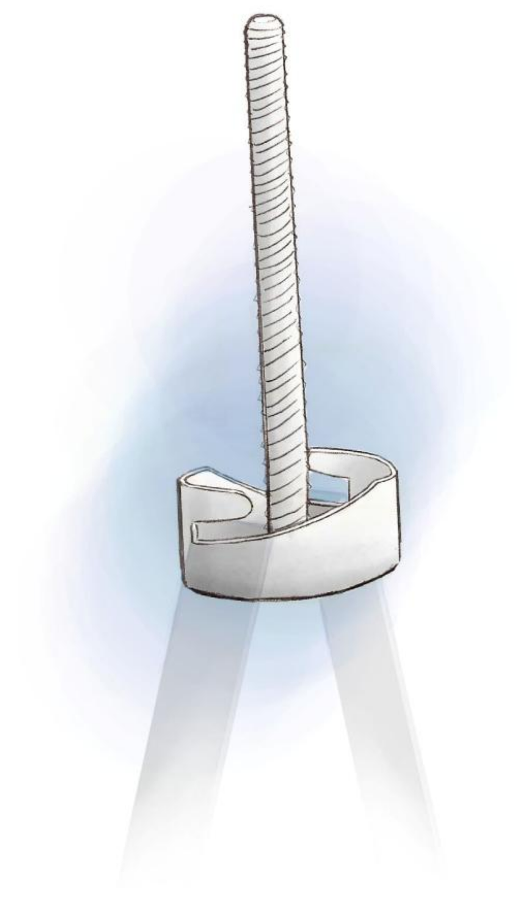
PRODUCTION A piece of steel band needs to be cut, bent and welded onto the hanger. Another option is to reform the steel band with the hanger. This means a ‘dent’ is made in both sections, mechanically merging them together. However, this causes weakness in the hanger, meaning the steel band needs to be bigger at the location of merging.





ASSEMBLY SEQUENCE The figure on the left shows the assembly sequences of the current support and that of concept 3 The first four actions of anchor setting and rod cutting are equal, but the sequence of concept 3 is shorter. It does not have the steps of pivoting the securing on the rod.

A downside of this concept is that the hanger needs to be put in at an angle. This will not be a big hindrance in installation since current supports are added quite similarly.



Concept 4

UNIQUE SELLING POINTS This one-component product comes in standard rod lengths of 15, 65, 115, 165, 215 and 265 mm. This means that the customer does not need to pre-assemble. The pipe's orientation and a one quarter turn secure the hanger, so no extra securing element is needed.

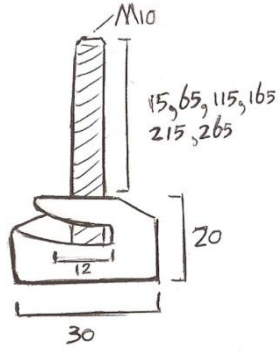
OVERALL ADVANTAGES

- Prevents need for height adjustments
- 3 components are merged
- Prevents need to cut thread
- Current components can be used

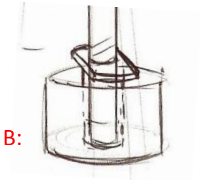
OVERALL DISADVANTAGES

- Height needs to be ordered
- Pre-assembly needed by supplier or Tyco

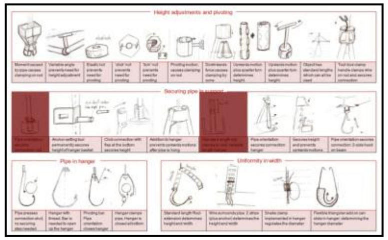
GEOMETRY The rod (M8 for pipes<DN50) is available in lengths of 15, 65, 115, 165, 215, 265 mm. This enables the pipes to hang on variable distances of 5 cm, no lower than 30 cm from the roof. 5 cm is chosen for the variations since this leaves enough possibility to maneuver around other pipes. 15 mm is chosen as a minimum length since this part of the rod will 'disappear' in the anchor. A hanger basket is fitted with cut-aways. These cut-aways must be at least 12 mm wide at any point, to fit the width of the hanger. When the standard hanger baskets are not high or wide enough to make these cutaways, option B can be opted; adapting the current basket hangers by partially covering the top. In this way, the hanger will still be secured pivoting a quarter turn.



Option B:

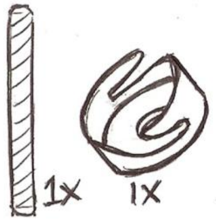


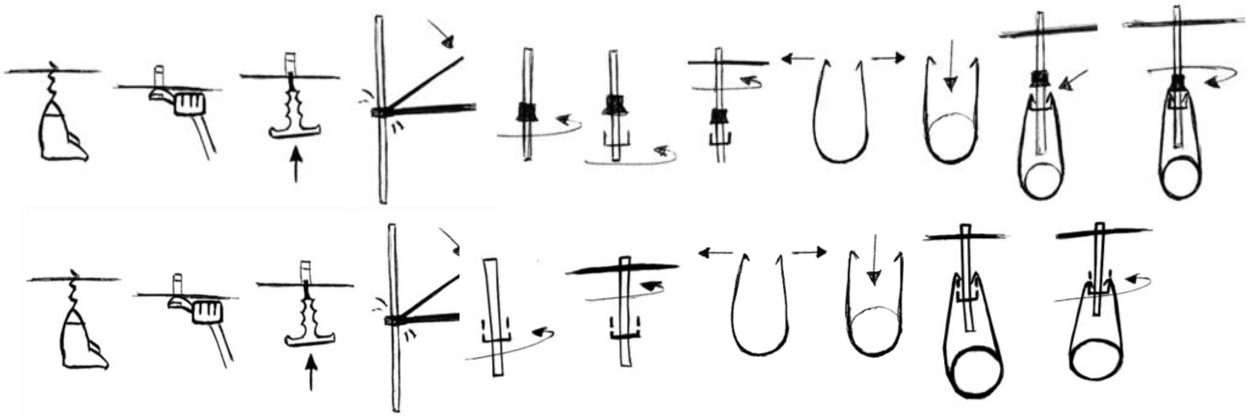
MORPHOLOGICAL SCHEDULE Since this product comes in standard lengths, it prevents the need for rod cutting and pivoting. This solves the problems for height adjustments without any of the solutions given in the morphological schedule. The geometry of the bottom half ensures the securing of the hanger. But this also limits the use of hangers; when another type than the current hanger is used (which is not rigid along its width) the geometry cannot guarantee to hold the hanger securely in place.



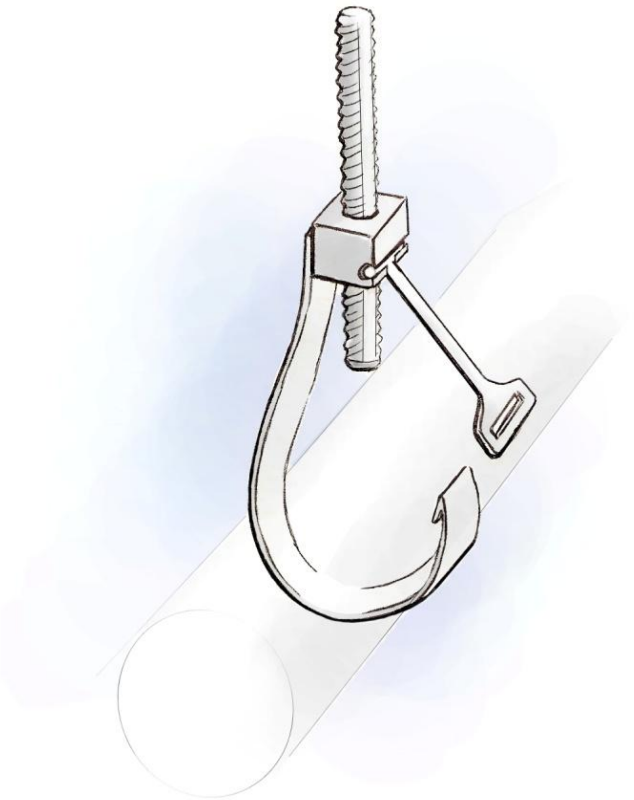
PRODUCTION Cutaways need to be made in the current hanger baskets. This will be done by punching holes in the walls before they are welded into a cylinder. When the basket is complete, the rods (which are cut in standard sizes) can be pivoted in the cylinder and permanently connected. This can either be done by a small weld or a local mechanical deformation to prevent pivoting motions.

When option B is opted, a small beam needs to be permanently fixed 5 mm above the opening of the cylinder. This fixing can either be done on the rod, or on the basket. In case it is only fixed to the basket, the rod and cylinder can remain non-permanently connected. This is more efficient in production, but will destroy the effect of the standard sized rods; leaving the customers assembling and cutting rods once again.





ASSEMBLY SEQUENCE Below figure represents the assembly sequences of the current support and that of concept 4. The first three actions of anchor setting are equal, but the sequence of concept 4 is shorter, only requiring pivoting motions and the bending of the hanger. The cutting of the thread, the most LABOR intensive step in installation, is removed. As well as the process of adjusting the hanger in height; assembly steps not even represented in the current assembly sequence.

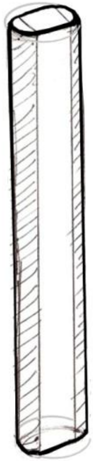


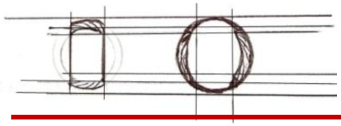
OVERALL ADVANTAGES

- Pipe orientation secures connection
- No pivoting motions needed
- No extra tools needed
- Easy pipe adding
- Only 2 components needed

OVERALL DISADVANTAGES

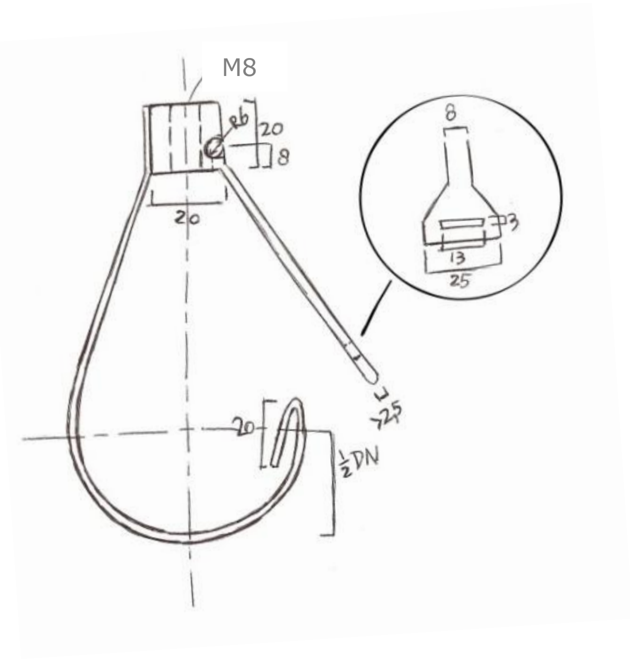
- Difficult to produce
- Hook increases chances of pipe damage during assembly
- Rod needs to be oriented





GEOMETRY The threaded rod is only partially threaded, the inner wall of the cube as well (M8 for DN equal or smaller than 50 mm). Figure above shows the threading on the rod (left) and the threading in the cylindrical hole in the cube (right). This enables the hanger to slide along the rod, but also secures it in place when a quarter pivoting motion is made. The geometry of the lever is so that the minimum cut-through section of 18 mm^2 is achieved everywhere. The length of the lever is such that it reaches the hanger at the centerline of the pipe, enabling the pipe to prevent the open-bending of the hook on the hanger. This hook is 2 cm long, any shorter and the chances of damaging the pipe will increase.

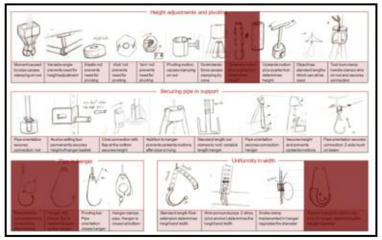
Besides a vertical cylindrical hole, the cube needs to be fitted with a horizontal one. This hole needs to be surrounded with material for (at least) 270 degrees to prevent the lever from falling out. At the bottom of the cube, a third hole needs to be made. This hole in the center of the side is at least 8 mm wide to enable circular movements of the lever.



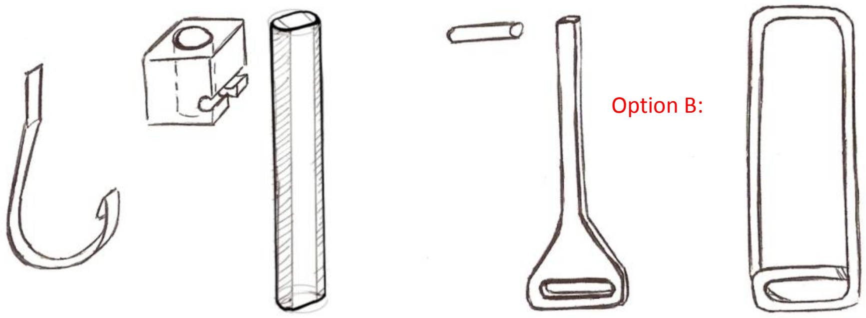
Concept 5

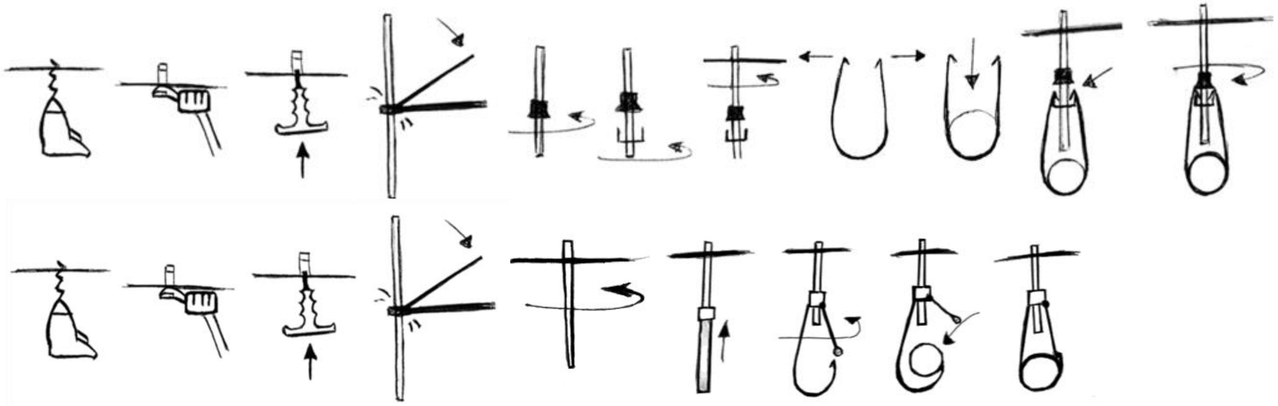
UNIQUE SELLING POINTS This product is a combination of two concepts. The partially threaded rod prevent the need for pivoting; letting the pipe orientation secure the height on the rod. The concept of the 'open hanger' prevents the need to hold up a pipe whilst assembling the support. It also does not require the hanger to be bend open in order to add a pipe.

MORPHOLOGICAL SCHEDULE This concept solves the problem of height adjustments by the partially threaded rod. The other aspect of this product is that it eases the adding of a pipe by the use of a lever.
These two solutions were merged since the open hanger requires a rigid top half, something which is also needed for the partially-threaded-concept. Would this rigid top half have been a hanger basket (such as in the current support) it would be able to rotate freely. In that case the pipe orientation would not secure the connection. (the solution pipe orientation for securing is not mentioned in the morphological schedule).
Width adjustments can be made with a triangular flexible add-on, but this is fully separated from the rest of the concept, so is left out of this concept. A description of this triangular add-on can be found in chapter 11 and appendix H.



PRODUCTION A steel band needs to be bent and cut as in the figure on the right. A cube needs to be made of steel and fitted with three holes: one centralized oval hole which is then partially threaded, one horizontal cylindrical hole on the side and one hole at the bottom which reaches the bottom of the horizontal cylinder. When the cube is finished, the steel band can be attached to it with a weld going round the edges.
An oval rod needs to be threaded (a circular rod cannot be used since it would have to be fully threaded, grinding parts of this rod would result in deformation of the thread, rendering it useless).
The lever is made from 2 pieces; a piece of rod and a punched shape. These need to be welded perpendicular to each other. This connection needs to be strong since it holds much of the weight of the pipe. Another option (option B) is to create the lever from a wireframe such as in the figure on the right.





ASSEMBLY SEQUENCE The figure on the left represents the assembly sequences of the current support and that of concept 5. The first three actions of anchor setting are equal, but the sequence of concept 5 is shorter. Concept 5 requires no pivoting motions and no labor-intensive bending of the hanger. The securing element however, is less efficient to operate than in the current support. The hook needs to be hung in the lever. This is a more difficult action than to pivot the securing nut .

Ch.12

Conclusions and recommendations

12.1 Conclusions

When looking at the competitive rivalry, it seems a logical step for Tyco to innovate. Tyco has enough buyers and suppliers to go around, but to prevent losing customers in the future, the step to go from a distribution company to a company with its own product ideas is positive. The assignment to bring more installation efficiency to the sprinkler supports through redesign was therefore logical.

But how to improve the supports?
Analysis on the logistics suggested that supports with few components, small packaging volumes, long hands on tool times with, suitable for multiple pipe diameters and heights, which can be assembled early on in the supply chain are efficient in installation.
But to do a redesign a list of requirements was needed. The definition of efficiency states that the reduction of the labor, time and money consumed around support installation would increase efficiency. So the constraints for the redesign became as following:

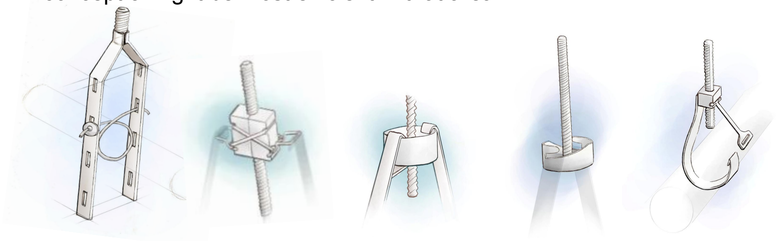
- For the labor aspect; no more than 5 components are used, preferably only 2. These components should have multiple functions. Current support components often have only one function, resulting in a flexible structure. However, sprinkler supports do not need flexibility since they are often not touched again after installation until they are destructively removed. Merging components would result in easier installation and rigid structures. The components most suitable for merging are the connection components (washers, bolts, nuts).

- Analysis on the money aspect shows that the concept should cost no more than 3.54 euro (the purchasing price of Tyco's most offered sprinkler support). However, 2% of a customer's overall project costs are in ordering the supports, but as much as 8% of the costs are in the time it takes to install them. This could be the argument to make the more time efficient concepts a bit more expensive.

- For the time aspect, new products should take up no more than 7 minutes to install. This includes the preparations of the components.

These 3 aspects would be the main constraints. However, the approvals, customer interviews and talks with product manager put further constraints on these constraints. The conclusions were that installation companies see supports as a side issue; little attention is paid to them. Components can be replaced in the assortment for optimization reasons, but fully new products are hardly ever accepted since the change is too big. Also, the time span for this project proved to be too small to change the way of anchoring. This meant that the thread within the current non-drill-anchors was to be used, even though the cutting of the rod is one of the most labor intensive tasks in installation.
Also, the feature to fit multiple pipe widths and heights was desirable. This would ease the processes in ordering and production.

When looking at these last constraints, concept 1 is most efficient. It is quick to install, easy to order and suitable for multiple pipe heights and multiple pipe diameters. However, the money aspect is still not tested since it is still unknown whether or not this concept is easy to produce and transport.
The main conclusion therefore is: The concepts as presented in chapter 11 are only tested on the labor aspect (which points concepts 1, 2 and 5 as being the most efficient, 4 as well because this prevents the need to cut rod). But whether or not these concepts are money- and time efficient is still unknown. This is for the successor of the assignment to find out. But a gut feeling tells that concept 3 might be most efficient in that area.



Concept	1	2	3	4	5
Assembly steps	8	9	10	10	9
Components	2	3	3	2 (or 3)	2

12.2 Recommendations

Because of the conclusions in this chapter I recommend Tyco to appoint a successor for this assignment as planned. This successor can focus on the production methods for these concepts and can make the concepts more money- and time efficient in installation. Very much intertwined with the production possibilities are the transport and packaging methods. The total packaging volume and weight are the main things to keep in mind.

But before all of this can happen, I recommend the successor to look at the geometry of the concepts more closely. An aid while doing this may be to investigate the current installation. Especially the most common distances from sprinkler pipes to roof and the most commonly used pipe width (most likely smaller than DN50). This will help form the final geometry of the concepts.
Then, after the final geometry is clear and the production methods are determined, test can be done on the TIME aspect. But this might be for the 3rd phase in this follow-up assignment. The strength and capability of the concepts need to be tested then as well.

Adding this information up, the following end goal can be formed:

"Through a *capable* redesign; reduce labor, *time* and *money* needed for the customers to deal with the Logistics and Installation of Tyco's sprinkler support products. Logistics being the Ordering, (removal of) Packaging and Transport."

Ch.13

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