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Resurgence of the Rack Infrastructure in a Multinational Steelwork Company

G. C. Victor

Abstract—The needs of modern-day businesses keep increasing and evolving in the digital era in which we are currently situated. The client, a multinational steelwork company in Poland that works with high temperatures in a hazardous environment, who needed to revamp its network infrastructure, reached out to Inserty, a leading business in the field of networking and communication. I then, as part of Inserty, was responsible for providing solutions that would satiate their needs. Once the pertinent study was carried out by me, while maintaining an open and clear channel of communication with the client, I discovered various areas of improvement: The old optical fibres that the client had could be upgraded and shielded from external agents, together with a change in its network topology in order to bring redundancy and ensure that the client´s operations would not cease working due to a malfunction or shut down. Due to the high-risk environment, the components of the Rack would be destroyed regularly. As a result, I formulated new Racks and Rack accessories that can adapt to the necessities of the environment, in order to make sure that the interior electronics would be protected. Once identifying the needs of the client and how to fulfil them, Rittal and CommScope, who are experienced veteran manufacturers within this field, provided indispensable aid to this project: They provided competitive prices for the Racks and their accessories, and their materials, which allowed me to offer an otherwise impossible invoice to the client. This is a real-life project. Since I am aware of the complexities within businesses and transactions, and the time frame it may require from the client's side to accept, the project presented in the following pages is taken as a proof of concept, in order to evade any issues.

Index Terms — Access Control Inputs, Cisco, Cooling Units, CommScope, Data centre, Inserty, Monitoring Systems, Multinational, Network topology, Optical fibre, Power Distribution Unit (PDU), Rack, Rittal, Uninterruptible Power Supply (UPS)

1 Introduction

THE client, a multinational steel company, decided, some decades ago, to increase their reach with the purchase of assets from a steelwork company in Poland – which has almost 200 years of experience in the manufacturing of both rolled and forged steel products. This also aided their desire to consolidate their presence in Poland, and in all the countries within its area of influence. It has become situated among the leading steel producers in Europe. Over these 18 years, the company has implemented improvements in furnaces and steel castings, although the physical communication networks and infrastructures are obsolete and have never been updated.

Now, the client has decided to develop a project to update the entire IT network and communications infrastructure of its Polish headquarters, in order to strengthen the security of their communications. This is a large-scale project, since it involves the redesigning of an entire system for a company that covers four square kilometres, with the total deployment of computer networks, data centre, monitoring and control software, among others.

Due to the nature of a business exchange, which fluctuates, constantly evolving, there are many moving parts at play. This exchange consists of two major players: the business and the client. As the business, I have control over the solutions offered in order to fit the client's demands. The client has control over their acceptance and subsequent payment of these solutions. As a result, this project is a proof of concept [8], meaning that its implementation is utilised to verify that a concept is feasible. In relation to this project, I will be designing the solution that the client needs, not focusing on the client's desire to finalise the transaction. Secondly, as the complete reformation of the networking communications is a large undertaking, my dissertation focuses on one aspect, the resurgence of the Rack infrastructure, of the overall venture.

I chose this dissertation as my proposal as it is an opportunity to carry out a large project from scratch, with a multinational company. This gives me a chance to delve even deeper into the real world of business and be able to observe the current panorama and state of current technologies, not only in a national territory, but also in an international one. This experience is nourishing me with technical, personal, and cultural knowledge. Offering me an extensive network of contacts, both engineers and businessmen, while also offering me custom training.

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2 The Client

The client has explicitly asked that they remain anonymous as their headquarters, located in Poland, are susceptible to danger and attack because of the Russian invasion of Ukraine. For the reader, this could result in some questions being raised as this may seem, at first glance, completely unrelated to the subject at hand. However, it is completely germane and has greatly impacted the course of work I had to follow.

As of the 24th of February 2022 [1], the Russian invasion of Ukraine took place. The company is situated in Poland, which is involved in the conflict due to its proximity to the countries at war. Furthermore, some attacks have already taken place: Russia bombed Lviv, a city nearby Poland, as a countermeasure to Ukraine resisting to hand over Mariupol [13].

With this in mind, several changes impacted the creation of my work: The client, who works with foundries at very high temperatures that are highly volatile, could become a tactical target to be attacked, as the damage it could cause would be immeasurable. As such, security in the client's premises has been increased. Likewise, I had to sign some documents that said I would not share any critical and/or sensible documents or information regarding the premises. As if they were to be made public and fall into the wrong hands, they could endanger the lives of Polish people. This would render the project completely null. However, after some discussion, I was able to continue my dissertation only and if only the following conditions were met: the client would remain unmentioned and all critical and compromising information was completely removed.

What does that mean regarding this dissertation? Nothing at all. As this is a proof of concept, the end result and the objectives remain unchanged. The reader will be able to see the processes and the work necessary to achieve said objectives.

2.1 The Premises

The client's company is one of the leading businesses in the surrounding territory, which has been in production for more than 15 years, as well as its installations and facilities. While the technology that they use has gone through a process of constant modernisation, optimisation and improvement, the fixtures haven't followed suit.

The industry has hold of more than $2km^2$ of area, with one central data centre. The rest of the premmises are divided in three different zones [Fig. 1]:

- Steelworks (Area 1)
- Round Rolling (Area 2)
- Lamination (Area 3)

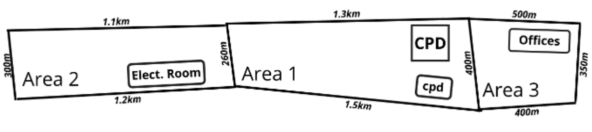

Fig. 1. Distribution scheme of the premises.

In Area 1 they do the steelwork: the trucks full of scraps come in and drop the scraps. They are then melted with chemical compounds that gives the newly created steel beams more resilience and protection. In Area 2 they do the round rolling: they are created by hot rolling continuously cast steel billets. In Area 3 they do the lamination, after the scraps have been turned into metal beams, they are then shaped in the lamination.

Each of these three areas are divided into smaller areas, they have one or various of the following:

- Offices ⇒ They are regular offices in which the workers do paperwork and communication.
- Stalls ⇒ They are offices located close to the Production areas or Foundries.
- Production Areas ⇒ Production area where the materials are distributed and/or worked on.
- Foundries ⇒ Very dangerous/hazardous and high temperature areas.

The whole layout contains over 20 Racks distributed throughout all the premises. In the middle, they have central data centre. This data centre does not need any Rack renewal as they are in good condition.

The same cannot be said about the ones located in the Offices, Stalls, Production areas and Foundries. As this is a proof of concept, I will work on the three different zones: Steelworks (Area 1), Round Rolling (Area 2), Lamination (Area 3).

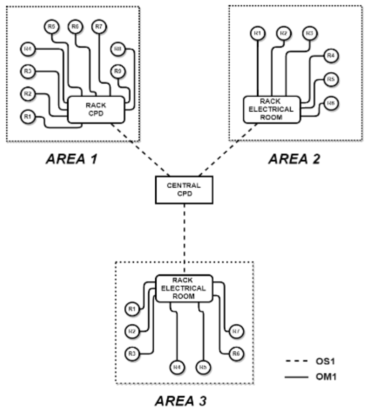

Fig. 2. Overview of the Rack connection scheme.

The central data centre is connected with single mode fibre OS1 (with 12 fibres) through every main node of every of the previously mentioned areas, in a star manner. Once it reaches said Rack, it swaps to multimode fibre OM1. Each of the zones have a main node location (a smaller data centre, an electrical room, some Offices) that act as the storage for the main Rack that is connected to the other Racks inside of each area [Fig. 2].

Both OS1 and OM1 are extremely old and are now on the decline, as they lack upgradeability and they simply cannot keep up with the demand, which results in severe limitations to the network at hand.

2.2 The Needs

The client does not currently perform at an optimum and maximum capacity. To do so, they would need a robust and scalable system infrastructure. As such, one of the first ideas that I conveyed to the client was the concept of "scalability", as it is of the utmost importance. Scalability describes the capability to cope and perform well under an increased or expanding workload, and/or growth. If the system scales well, it would be able to maintain or even increase its level of performance and efficiency even when it is faced by larger and larger operational demands.

We need to keep in mind that, if the infrastructure of the company is scalable, so is the company: the business obtains the ability to handle increased market demands. A scalable company is one that can maintain or improve profit margins while the operational demands increase, without being hampered by its structure or available resources. When achieved, the infrastructure becomes capable of processing bigger and larger quantities of complex data when the occasion demands it.

The client also needs to guarantee that there will be an uninterrupted flow of data and communication, since, if one Rack stops, a large list of consequences arises: it could set back productivity timelines causing the loss of current and future business, it could render the workers completely helpless as their systems are not responding… Whether from a heat problem, a power cut or a system error, the solution has to guarantee the continuation of production and the protection of the hardware.

Time is money, and wasted time is the loss of opportunity and gain.

So, then, I will propose improvements regarding the upgrading of the communication between the different Racks. I will also be upgrading the Racks, per se, so they include the accessories that are necessary based on their needs, aiming to extend the longevity of the equipment they store. The accessories include UPS, Cooling Units, and CMCs, among other things.

3 STATE OF THE ART

It is necessary to present to the reader two different, yet connected fields regarding the state of the art: the first being the Rack shelves and the other being the optical fibre.

Modern day businesses have to constantly face an increase of data and information that needs to be processed, as such, the quantity of hardware stored and needed increases a substantial amount. Before, the electronics could be stored in a Rack with no additional components. Now, additional components are a must to be able to preserve and protect the equipment. Guarantying a non-stop flow of information and communication.

Due to the fact that the thermal emission increases proportionally to the hardware stored inside the Rack, the concept of cooling units is needed. As if the temperatures inside the rack were to rise to dangerous numbers, the components would be damaged, with all the ordeal that would follow. The cooling units [Appendix. A2] allows for an air flow exchange, expelling the warm air outside.

The electronics inside of the Rack are still dependant on an external power supply, be it the electrical power that comes from the general electrical line or other lines. If that line stops working the Rack's electronics would be rendered unusable. An Uninterrupted Power Supply (UPS) [Appendix. A1] works as a middle man between the power supply and the Rack, activating when it detects that the powers supply is no more. It takes the role of a generator, supplying the powers needed for the Rack for a certain duration.

Decentralised solutions become more and more common in fast-paced international modern businesses. It is because of that fact that intelligent monitoring solutions are a must. Solutions that allow the interaction and manipulation of the equipment from afar, even from different countries.

It is also important to mention the current state-of-the-art that is present in optical fibre. Optical fibre, like the majority of cabling components, seeks to offer the highest transmission speed possible with the maximum metres. Fibre optics cable is used for high-end applications. Multimode optical fibre has evolved from its origins at type OM1 all the way to OM5. The latter being more scalable and flexible, which can support higher-speed network transmission with fewer multimode fibre cores [6].

Indirectly, during this project, my aim was to bring the client a solution that comes as close as possible to the state-of-the-art concept present in the industry, which will be introduced in the following pages.

4 OBJECTIVES

As mentioned above, the main goal at hand is the resurgence of the Rack infrastructure at the client´s premises. Below are the objectives that will allow me to achieve this main goal:

1. Resurge the Rack infrastructure of the client´s premises.
   - 1.1. Carry out an audit at the headquarters to see, in more detail, the state of the physical installations.
   - 1.2. Prepare the materials/equipment which could cover the client's needs.
     - 1.2.1. Undergo training in Racks, data centres, equipment, etc., by the providers and/or manufacturers, and Inserty.
   - 1.3. Design the Racks with the corresponding accessories.
     - 1.3.1. Design Monitorisation and/or Control Access in the Racks where necessary.
   - 1.4. Design the new Rack infrastructure.
   - 1.5. Develop the economic budget for the implementation and start-up of the global project.

4.1 Optional Objectives

Depending on different factors which I have no control over, some of the previously discussed objectives are optional and may or may not be conducted. It is important to stress that I only have control over the solutions offered in order to fit the client's demands. Whether they accept or the time it takes them to accept may be far beyond the scope of this dissertation. As such, below is an explanation of the optional tasks:

- Carrying out an audit at the headquarters of the client to see, in more detail, the state of the physical installations, as well as the Rack cabinets. This is where the communications equipment and all the necessary equipment will be housed for power and cooling of servers, storage units, and switches. In addition, other physical parameters of the equipment and the room, such as power supply, temperature, consumption, etc., will be checked. Furthermore, all sections within the security of access and control of the spaces will also be checked.

- Obtain training in Racks, data centres, equipment, etc., by the providers and/or manufacturers, and Inserty. This would increase my knowledge in data centre and tech rooms by the hands of knowledgeable and professional businesses.
- Design of Monitorisation and/or Control Access in the Racks where necessary, if the client approves.
- Development of the economic budget for the implementation and start-up of the global project.

Again, regarding these last two points, it is very important that the reader understands that the fact that the client accepts (or the time it takes them to accept) may be far beyond the scope of this dissertation. Thus, designing the Rack monitorisation, the control access, and the development of the economic budget may occur too long into the future, if at all.

5 Methodology

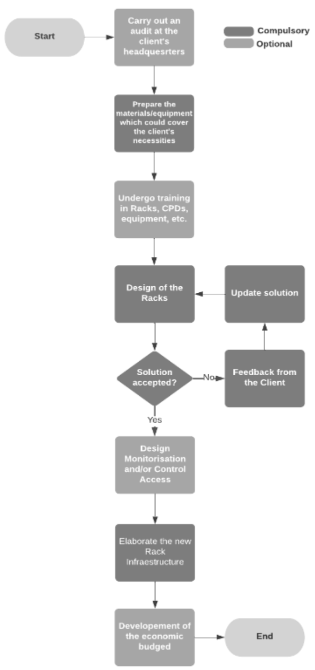

Fig. 3. Methodology flow followed during the development of the dissertation. It includes both the Waterfall methodology and the Prototype methodology.

The objectives that must be fulfilled need to follow both an iterative and linear flow. Regarding the linear aspect, I thought about using the Waterfall methodology [16]: this attends to the needs of linearity, as the sequential order accommodates the main flow. This linearity can be seen in the objectives, carry out the audit, undergo training in the materials, present the rack solution, design the monitorization, elaborate the new infrastructure and develop the economic budged. As for the iterative attributes, they are satisfied by the use of the Prototype methodology [11]: this system allows for the development of a solution, which is then tested based on the feedback from the client and then reworked. This cycle iterates until a valid solution is reached. The result of combining both methodologies can be seen in [Fig. 3], presented below. The optional tasks could be completely removed without affecting the overall flow of the project. The same cannot be said about the mandatory ones, as they are necessary and compulsory.

6 Improvements

6.1 General Improvements

6.1.1 Fibre Type

The first problem that can be seen is the age of the infrastructure, as it is over 15-years-old. This fact raises several problems: the prospects of today's available resources far surpass what its current state can offer. As such, the solution becomes quite clear: there is a strong necessity to change and upgrade the cable to a more modern one.

Regarding the single mode fibre OS1, it could stay the same, as the upgrade to OS2 does not bring much benefits, as the total distance is less than 10km. However, by the client´s request, the fibre is to be changed from OS1 to OS2. By doing so, even if both of them achieve speeds of 10GB, their maximum attenuations will, in fact, change: for OS1 it is 1.0db/km and for OS2 it is 0.4db/km [17]. Regarding the OM1, it should be upgraded to OM4: as the OM4 can maintain distances of up to 550 metres, in contrast to the only 300 metres OM1 can achieve [17]. The new distance allows me to modify the position of certain Racks and optimise the coverage and their range.

6.1.2 Protection of the Fibre

The client has informed me that the fibres at some locations are prone to burn and break due to the high temperatures and the harmful medium that makes its presence in some parts of the factory. As such, as requested by the client, the fibre will wear a protective sleeve against high temperatures which will render it immune to fire and ignition [15]. As this sleeve is extremely expensive, it will be only included in some parts of the course that the cable follows.

The client has also expressed their fear towards rodents sometimes biting and eating the fibre, which causes large shutdowns and affects the activity of the factory. As such, the fibre will be rodent-proof: by offering an armoured cable, which is a type of cable either covered by mesh or a metal pipe tube. It will not only protect against rodents, but also it will prevent the coupling of noise and other interference, both from the environment to the cable, and from the cable to the environment.

6.1.3 Network Topology

The current network topology is the Star type [7]: the distribution of the information goes from a central point (main data centre), to all the destinations or nodes of the network (area 1, area 2, area 3). The schematics of the topology can be seen below [Fig. 4].

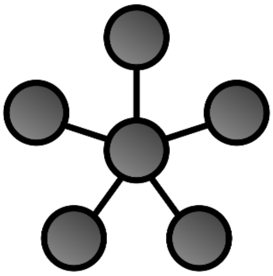

Fig. 4. Showcase of the Star topology, where the different nodes are physically connected to a central node.

In this instance, the main data centre does all the work (acting as some kind of local server that manages the information). However, if one of the connections fail, the whole node in the area will fail.

To be able to fix this, we need some kind of redundancy. After proposing a variation of the star topology to the client, with the difference being having two fibres go from each node, instead of just one, they declined: they wanted all the nodes to be connected between them. In other words, to connect the main nodes of each area between themselves, plus the previous connection they had with the main data centre. To achieve this, a Mesh topology [9] is needed: this is a setup where each network is interconnected with one another [Fig. 5].

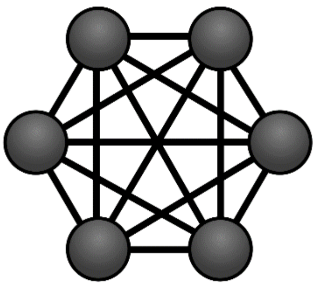

Fig. 5. Showcase of the Mesh topology, where the different nodes are physically interconnected with one another.

This topology setup allows for the most transmissions to be distributed even if one of the connections goes down. By adding an OS2 fibre cable that connects the main nodes of each area among themselves, we are guaranteed that, even if one cable fails, the whole network will continue working.

That would result in a total meterage of 3.000 metres of OS2 fibre to change the previously OS1 fibre that generated the star topology. Regarding the new fibre necessary to achieve the mesh topology, another 5.500 metres would be needed. For the upgrade from OM1 to OM4, the first area would be a total of 6,000 metres, the second area 2,500 metres and, lastly, the third area 2,000 metres. That would add up to a total of 10,500 metres of OM4.

6.1.4 Racks

One of the main focuses that has been presented throughout the whole of the dissertation has been the need to change the currently unprotected Racks and make them more loyal to the needs of the client.

First, it is of the utmost importance that the concept of a Rack is understood, as the whole project revolves around it: it is, then, a shelf in which various hardware can be stored in an ordered, more optimum, and organised manner. When it comes to cabling huge network connections, Rack shelves can manage these networks effectively.

The advantages of using a Rack include the fact that it maximises the available space, it protects the hardware, it enhances air flow circulation when coupled with a cooling system, and it eases regular computer maintenance and diagnostics, given that their design allows technicians and operators to easily slide the components inside in and out of them.

They will be explained in more detail in each of the areas and their particular needs. If the components inside are protected, they are less prone to failure, which translates into money saving both because production will not stop and also because the client will not need to spend more on replacements. The client has shared their intention of keeping the same components inside the Rack, without the need to change them. The mentioned components are not old, as they have been constantly changed, otherwise they would have melted.

Seven different Rack types [Appendix. D] have been created to accommodate various needs in different areas of the client's premises.

6.2 Steelworks (Area 1)

This is the biggest area of the tree, which turns it into the main focus of the project as the grand stepping stone towards the resurgence of the client's infrastructure. In this section, again, I will break the following improvements into different sections, as to make them clearer. However, before we move forward towards the solution implemented, it is necessary to describe the first area.

As mentioned above, this is the largest one. This can be explained due to the fact that this is where they do the steelwork, and the trucks full of scraps have to fit and be able to drop the scraps off in this area. The other part of the area is full of high temperature foundries that will melt those scraps.

The area contains a total of 9 Racks. Those Racks are connected to the smaller data centre, which then is connected to the main data centre, which is also in the first area. Out of the 9 Racks, the distribution is as follows:

- 4 Racks in the foundries
- 2 Racks in production
- 2 Racks in the stalls
- 1 Rack in the offices

6.2.1 Foundry

The foundry is in charge of melting the scraps and plays an important and main role in the whole of the premises of the client, as it is the start of a chain that will transform those scraps into resilient and strong steel pieces.

That is why the biggest part of Racks distribution dwells into this part. The current state of the shelves is completely deprecated: they melt due to the high temperatures and are completely unprotected against dust and other harmful particles. Their components are also melted and sometimes even explode because of the generated heat.

This distribution is due the fact that there is one Rack very close to the actual industrial oven which covers a big section. Even if both types offer the maximum IP of protection [14], I wanted to make sure that the components inside of it would not be damaged, thus, the redundant cooling units ($2n$) of the type 7 are needed in this instance. The other three Racks will be type 6, as they need protection from the harmful agents outside, but do not require redundancy. In this instance, the following Rack types will be needed:

- Type 6 x3
- Type 7 x1

6.2.2 Production

Once the product is melted and the chemicals have been added, it is then transported to production in a special truck that can hold extremely high temperatures that the melted steel emits. Here they shape the melted steel into big beams. They have two Racks there that take care of the machinery that produces the beams. The temperatures are lower than in the foundry; however, the main issue here is the steel dust that it generates.

This offers a high degree of protection against the large quantities of steel dust, making it so it will not interfere with the components inside the Rack and damage them. This increases the longevity of the equipment and, also, the correct operating and functioning of the production chain. In this regard, the solution becomes clear:

- Type 6 x2

6.2.3 Stalls

The stalls are used as monitoring for both the foundry and the production. It is a cabin with monitors and computers that follow and control the chain that the steel follows. The client has two stalls in this area: one for the foundry and the other for the production. The situation and state of both of them are the same, as they are away from the extremely hazardous locations. However, they are still prone to some of their effects, even though they are not next to the cause. The solution here becomes the following:

- Type 3 x2

6.2.4 Offices

The paperwork and communication happen here. It does not get affected by high temperatures and the room already has air conditioning on its own. After studying the current Rack, some of its components were allocated outside as there was not enough space inside, ending up on the roof of the Rack in question.

Based on that, two things could have been done: either adding another Rack or increasing the size of the Rack. The choice I took was to increase the size, as that would mean that the rest of the connections that Rack had could be maintained. That way, the weight can be increased and some space is freed. As such, the necessary Rack here is:

- Type 2 x1

6.3 Round Rolling (Area 2)

The second area is responsible for doing the round rolling, which refers to the process in which the steel is rolled above the recrystallisation temperature by continuously casting steel billets. So, after cooling at room temperature, the steel is normalised and cooled to become a hot rolled finished and completed steel product.

This is the second largest surface. In this instance there are no foundries; however, there are three different production sites, each with their own Rack. It has two stalls, which does not correspond with the number of production parts, three; however, one of the stalls controls and surveys two of those production processes. Lastly, they have the offices, being the smallest out of the three areas. There are a total of 6 Racks altogether, and the distribution is the following:

- 3 Racks in production
- 2 Racks in the stalls
- 1 Rack in the offices

6.3.1 Production

In this instance, the main problem the Racks had was very similar to the production in area 1: the steel dust would damage the components inside and, thus, render them unusable.

By doing so, the Racks are protected both from the dust and the temperatures, not as high as the previous area; however, still high. The solution presented is the following:

- Type 6 x3

6.3.2 Stalls

In this instance, there are two different stalls, one of them however, does the monitorisation of two production zones. This is where the focus will lie, as the client has explicitly asked me for the separation of some components that lay in the previous Rack: The Rack had the equipment necessary to connect to the two production zones plus the computers that would monitor the whole process.

They have asked me for a way to separate the computers from the rest of the components. The solution for that is to add another Rack. This will be the type 1 Rack, as the computers do not generate much heat, and the room already has an air conditioning system that will dissipate the warm air that the cooling unit emits to the outside. Then, the Racks necessary will be:

- Type 1 x1
- Type 3 x2

6.3.3 Offices

These offices are smaller compared to the ones in the previous area, the Rack could have been maintained; however, after deliberating with the client, it was agreed that this Rack should also be changed. As such, the necessary Rack here is:

- Type 1 x1

6.4 Lamination (Area 3)

In this third area the lamination is done: after the scraps have been turned into metal beams, they are then shaped in the lamination. The material is positioned in place on the cutting board, then it is bonded in place, and then the necessary shape is cut from the layer, by laser.

This is the area with the smallest surface. In this instance, same as the previous area, there are no foundries per se; however, again, there are three different production sites, each with their own Rack. It has three stalls, each one of them controlling and monitoring each of the production zones and their processes. Lastly, they have the offices, of which the client is planning on increasing. There are a total of 7 Racks altogether, the distribution is the following:

- 3 Racks in production
- 3 Racks in the stalls
- 2 Rack in the offices

6.4.1 Production

In this instance, the main problem the Racks had was very similar to the production in both area 1 and 2: the steel dust would damage the components inside. This solution can be exported, as we have seen, to all the production zones in every area of the premises.

The solution presented is the following:

- Type 6 x3

6.4.2 Stalls

In this instance, there are three different stalls. Even if there are more in quantity compared to the previous areas, they are smaller. And the workload they have to face is also smaller, thus there is no need for extra Racks to be added.

- Type 3 x3

6.4.3 Offices

The offices are the main focus of the third area, as the client is planning a project to change the layout of the offices, which will merge and increase their total number. Even though there is only one Rack currently distributed, the client has asked for a total of three Racks in this premises.

The current Rack's original position will be kept; however, due to the fact that the offices will grow, another Rack will be necessary. After presenting them with the Type 4, which can store two individual Racks, they loved the idea to have a more centralised solution. The third Rack, however, is planned to go in another building that is planned to be built next to the current offices. As such, the necessary Racks here are:

- Type 2 x1
- Type 4 x1

7 Viability Study

Once the results have been presented, and with that, the solution that reaches and accomplishes the objectives, it is of the utmost importance to undertake a viability study [10]. There are two main parts of a viability study that must be observed: the temporary viability and the economic viability.

I will direct my attention to those fields as they bring important information that both the client and I, the business, need to know for the extracting the solution and making it a reality. The temporary part is foundational for the planification of resources versus time. The economic part is fundamental for the economical transaction that would happen in the future, if any.

7.1 Temporary Viability

This is, without a doubt, a large-scale project. With a total duration of 1921 hours. It is necessary to convey that the information shown in [Table. 1] is formulated based on the concept that one day has 8 working hours and, one week has 5 working days, not taking into account any holidays that may arise.

	Hours	*Days*	*Weeks*
Mesh	*781*	*157*	*19*
Area 1	*608*	*76*	*15*
Area 2	*281*	*35*	*8*
Area 3	*251*	*32*	*7*
Total	*1921*	*241*	*49*

Table 1. Breakdown of the hours, days and weeks needed to undergo the Resurgence of the Rack Infrastructure.

The total distribution falls mainly into the mesh creation/link fibre upgrade and the Area 1 [Fig. 6]. That is due to the fact that those two are physically bigger and require a bigger workload. On the other hand; however, as both the Area 2 and Area 3 are physically smaller, in comparison, the time required to execute the work is reduced.

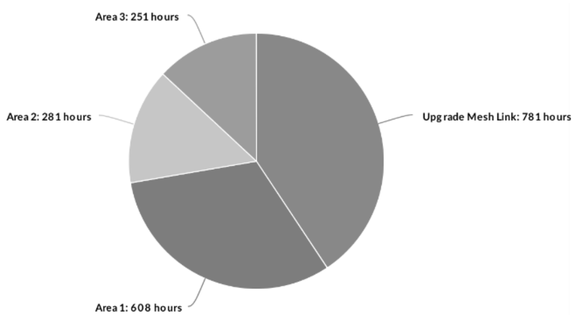

Fig. 6. Total hourly distribution of the Resurgence of the Rack Infrastructure at the client's premises.

The client has not shown any disagreement towards facing the execution of the project in a linear manner. That means that there will be no parallelism: two areas will not be worked on at the same time, once one area is finished, the personnel will swap to the next area.

If the project were to be accepted, the first area to be done would be Area 1, as it has the most critical Racks, followed by Area 2, the Mesh upgrade and, lastly, the Area 3. That is what the client feels more comfortable doing and what they shared once I had presented them with the solution and the invoice offer.

7.2 Economic Viability

As for the economic part, the total cost to undergo the project adds up to a total of 1.032.165€. This cost can be broken down and distributed into each of the different areas and costs types [Table. 2].

	COSTS (€)			
	Materials	*Labour*	*Racks*	*Total*
Mesh	*13.583*	*25.677*	*-*	*39.260*
Area 1	*32.703*	*21.236*	*348.468*	*402.407*
Area 2	*11.810*	*10.344*	*242.171*	*264.325*
Area 3	*10.380*	*9.712*	*306.075*	*326.167*
Total	*68.476*	*66.969*	*896.714*	*1.032.159*

Table 2. Breakdown of the economic cost to undergo the Resurgence of the Rack Infrastructure

The total cost of the undertaking of the Resurgence of the Rack Infrastructure can also be divided to show what the individual cost of each area is [Fig. 7].

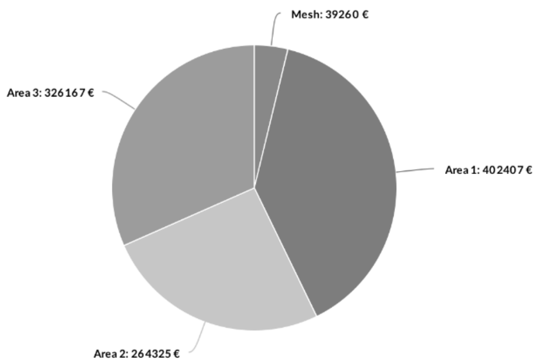

Fig. 7. Total economic cost to undergo the Resurgence of the Rack Infrastructure divided by Areas.

In this instance, the Mesh upgrade takes the smallest portion, if compared with the portion it took in the Temporary Viability. We are able to observe that, even if there are more hours of work, there are no Racks needed. That being the cause of its current economic cost.

The client has received an invoice with all this information. The delivery of the economical budget was the final part before reaching the end of the scope of the dissertation. The acceptance of the invoice from the client, if at all, or the time they take to accept, if any, is not, as said previously, included in the scope of this dissertation.

8 IMPLEMENTATION

The client has specifically shared with me that one of the most important and utterly necessary things is the ability to continue the chain of production while the resurgence of the infrastructure takes place.

The client cannot (and will not) cease the operations they undergo as it would mean a loss of millions of euros, assets, and opportunities. That is why I have reassured them that there will be no need to stop production; while the implementation is taking place, it can be done parallel to the current infrastructure.

This can be achieved by assembling the new Racks next to the old ones and installing the fibres while keeping the old ones. This will follow the already mentioned order of Area 1, Area 2, Mesh and, lastly, the Area 3.

The client has, as they call them, “stop weeks”, which means that, during the year, there are some weeks that the premises undergo a complete stop. Of course, that window of opportunity would not be enough to build the new infrastructure; however, it is plenty of time to change the components from the old Racks to the new ones and connect them to the new and already deployed fibre.

By first doing the time-consuming work and preparing the infrastructure for the change when the opportunity arises, then it is possible to undergo the total restoration of the infrastructure without having to stop production for long periods of time.

Once the Racks and the fibre are in place, next to the already existing ones, with the hardware adaptation, explained below, having taken effect, it is necessary to wait for the stopping weeks. Before the stopping week; however, to optimise time, a planimetry could be arranged. A planimetry consists of writing down the connections that each hose has so they can be emulated in the solution to give connection and communication to the infrastructure. After that, it would be a matter of swapping the hoes from the old fibre distribution boxes to the new ones, moving the equipment from the old racks to the new ones, making sure that all connections remain adapted to the new layout.

8.1 Hardware Adaptation

It is important to understand, before proceeding with the explanation of this section, that, this dissertation does not take into account the change of the hardware and electronics inside the Racks. This section seeks to give some light into the process of adapting the new solution proposed to the current hardware available at the client’s premises and it appears here for completion reasons.

This adaptation is not, and will not be undergone by neither Inserty nor me, but by a third party, which specialises in this field. I will explain some of the actions that they will have to undertake in order to adapt the change of hardware for the new solution to work.

Currently, the switches inside each Rack do not support the redundancy that the mesh topology offers. To do so, an intelligent switch that understands when a line is offline is needed to redirect the traffic from its ports.

Currently, as of today, before the installation has even begun at the client’s premises, the fibres have an ST connector [4], which is already in disuse. This is due to the fact that the fibre is extremely old. To be able for the ST connector to connect to the actual switches, the client uses a gigabit interface converter (GBIC) [3], which goes in a small hole, standard for all electronics. This GBIC allows the LC connector of the fibre to communicate with the electronics. As the fibre is getting revamped with the new solution, they will also need to change the GBIC connector to ST to a new GBIC connector to LC.

9 Conclusion

Working on this project has provided me insight into an international scheme and how the business and technical world works. From directly meeting with the client to understand their needs and their state, to contacting the manufacturer and the distributor to obtain more in-depth knowledge, both technical and interpersonal.

This is, by no means, a small project. On the contrary, it is a massive one that would require a lot of resources to take place and come to fruition. Thanks to the planning I underwent and the efficiency I followed; I was able to deliver the proof of concept to the client. I had to manoeuvre through some setbacks; however, they did not interfere with the end result and the presentation of said results.

The only objective I was not able to complete, which was an optional one, was the fulfilment of the audit: the undergoing of the audit had to be cancelled, as it would put our personnel (myself included), in grave danger, because of the reasons I have previously discussed.

The solution of changing the fibres provides the client with an undetectable downgrade of the speeds that distance causes, as they are still inside the limit. This results in more efficiency and a more optimum system. This also becomes increased by the change in topology: in the unfortunate case that any fibre cable that is connected to the main nodes would stop working, the network would continue working normally. Before, however, that would not have been the case. The whole node would have fallen and losses would have been generated. There are other small fixes that, even being small details, bring important advantages: the shielded fibre and fireproof cover, which guarantees even more uptime for the whole production.

The solution to change and adapt the different Racks in each one of the areas also yields benefits: as the components are protected, they are less prone to damages and failures, thus granting more uptime. The less they break, the less money the client has to invest in replacements. Visually, the image that the client gives to both their workers and outside visitors is a clean and presentable one.

This solution is also exportable: it can be used for other headquarters the company may have in other parts of the world. The steel works processes that they undergo are very similar in all of their headquarters, so this solution and the study behind it could be used for the future developments and resurgences of the other hubs.

10 Future Pathways

There is; however, plenty of room for improvement regarding the current solution. If someone else were to resume the project once this has reached its end, it would be wise to face some challenges that would bring greater improvements and advantages to the client.

One of the possible pathways to follow would be to study the hardware and electronic equipment which make up each rack: the same elements inside the Rack have been contemplated; but they could be studied and then changed and/or upgraded to become more optimal. As the solution has been generated with the concept of scalability, further improvements can take place without additional issues.

This concept can be delved into even deeper, and the copper cables that provide coverage to the machines could be also upgraded: they currently have UTP Category 6 data cable, which could be upgraded to UTP Category 6A [12].

The solution is completely replicable and exportable: as the headquarters of the client around the globe have the same functions, they also have the same processes and very similar layouts. It is because of this that the same exact Rack types could be applied elsewhere in the countries the client has a presence, even the solutions regarding the fibre. However, it is important to say that the meterage will slightly vary regarding the different locations.

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APPENDIX

A CONTEMPLATED RACK ACCESSORIES

A.1 Power Distribution Units (PDUs)

PDUs are, essentially, industrial-grade power strips used (in most cases) to power servers and hardware. They are born from the need to plug a lot of devices into a power supply, as plugging them directly to the main power supply would be impossible and dangerous. PDUs allows the distribution of the site's power to each individual device. This is possible because a PDU turns one (or a few) power inputs into many (they can change depending on the PDU) power outputs.

In other words, a power PDU is responsible for distributing reliable network power to multiple devices. It is important to say, however, that it can't generate power and it is not a secondary power source. It can deliver power from an uninterruptible power supply (UPS), a generator, or utility power to the remote equipment.

In the boundaries of the resurgence of the Rack infrastructure, Intelligent PDUs will be utilised: they are an important part of an integrated monitoring system that protects critical equipment. An efficient Intelligent PDU will allow the monitoring and control of the power at individual outlets, switch power on or off, remotely shut down the power during an emergency power outage, and also allocate power efficiently.

A.2 Cooling Units

Racks are a source of constant head generation, as high temperatures can seriously undermine the performance and longevity of all the equipment in server Racks and is prone to cause irreversible damages, rendering the Rack unavailable, affecting the whole production of the group.

That is the reason why cooling units are necessary: They cool down the hardware placed within closed Rack cabinets and they avoid the mixing of warm and cold air, which is the factor that causes loss in almost all server rooms. Cooling units usually use refrigerant or chilled water as the cooling medium. Even though there are exceptions, most products tend not to bring liquid into the server Rack.

A.3 Uninterruptible Power Supply (UPS)

An Uninterruptible Power Supply (UPS) is a battery backed power management device that is placed in the chain between IT infrastructure and electricity feeds. The primary role of any UPS is to provide short-term power when the input power source fails, preventing the corruption of the system due to unexpected server shutdown. Also, most UPS units are also capable in varying degrees of correcting common utility power problems.

Regarding the amount of battery backup that it can deliver, it depends on the load and the battery capacity. In many cases it bridges the gap to allow supply to be re-established. UPSs are given a power rating in volt-amperes (VA) that range from 300 VA to 5,000 kVA. This rating represents the maximum load that a UPS can support, but it shouldn't match exactly the power load necessary. The best practice is to choose a UPS with a VA rating that is 1.2x the total load needed to be supported.

A.4 Console Manager Controller (CMC)

The Console Management Controller (CMC) is a piece of hardware, which has visual and audible alarms, used for intelligent Rack environmental monitoring and controlling. The appearance of a CMC answers the call for the control of all devices/equipment of the data centre.

Several pieces of equipment and hardware are connected to the CMC, they include: air conditioning, UPS, PDUs, generator set, fire system, and communication Racks. It is also used to control sensors and alarms including temperature, humidity, smoke, vibration, security, and Rack fan controls. It has additional options, like controls, sensors, and locking capabilities.

It enables data centre managers to perform an accurate, automated, real-time inventory of all IT assets and their locations. Easily tracking assets, determining capacity in various areas, and managing or changing equipment, while making energy consumption more efficient.

B Contemplated Monitorisation Elements

Having a rigorous monitoring system in place is a must for any business that has a substantial Rack amount, as the failure of one, can cause the complete failure of the system. A good monitoring system allows improved data capture.

The sensors have the potential to revolutionise the way we manage information: they allow the collection and analysis of even richer sources of data, arming the business with the information it needs to act in case of any hazard that could damage the equipment. Those hazards are being identified in real-time, which delivers the insight of the current state of all the infrastructure. Businesses capturing this type of data become better-informed and more agile, more able to act against failure as a result.

They bring increased efficiency and productivity. The sensors have a positive impact on helping technicians find the cause of the sudden failure: instead of having to check all the possible Racks that could be the reason for the production abruptly stopping, the sensors will provide live data and inform them of the reason and place of the failure. However, the main feat of sensors in a tech room is safety and security, which are other key areas: A safe, secure environment is a comfortable, productive environment. The sensors are able to detect anything from an open door or broken window, to even monitoring a leak in the server room. By implementing a monitoring system, you can have peace of mind knowing that your business is safe and secure.

The proposed monitoring system is conformed of the following items:

- Temperature sensor.
- Humidity sensor.
- Leak sensor.
- Power supplied to each equipment connected to the PDUs.
- CMC (depending on the number of elements).

This system makes it possible to monitor the physical and logical parameters that may compromise the stability of the tech rooms and data centres, transmitting the appropriate alerts in the event of a critical event. If the number of elements increases, a PDU will not be enough to control them, as such, a CMC will be needed.

The parameters and alerts can be consulted through a centralised control interface through a web browser. Alerts caused by critical events are transmitted via email to different recipients or groups of recipients based on a hierarchical order derived from the segmentation of responsibility for elements or criticality of the events.

B.1 Temperature Sensor

Temperature sensors measure heat to detect changes in temperature. The Racks used in tech rooms are sensitive to temperature and have to be protected from overheating. With smart temperature sensors, businesses can detect failures or faults as they happen.

A temperature probe is installed in the data centre to monitor these variables. The power supply takes place through the CAN-Bus interface and indicates the status of the room by means of multi-LEDs.

B.2 Humidity Sensor

Humidity sensors are electronic devices that measure and report the moisture and air temperature of the surrounding environment where they are deployed. Specifically, humidity sensors enable real-time monitoring of humidity to identify problems (e.g., potential leakages) before they occur.

In these ways, humidity sensors extend the lifetime of critical Racks and maximise their overall efficiency. A humidity probe is installed in the data centre to monitor these variables. The power supply takes place through the CAN-Bus interface and indicates the status of the room by means of multi-LEDs.

B.3 Leak Detector

They are devices that serve to provide an alarm or visual indication of the presence of a leak from a pipe or other system that contains liquid or gases. Generally, leak detection technology centres around the concept of detecting a potential issue and then taking direct action to mitigate damage that can result from the leak.

Leak sensors are used in industrial and commercial applications but are also becoming more prevalent in residential settings owing to the widespread damage that can result from water leaks from pipes, appliances, or other fixtures in the home. The power supply takes place through the CAN-Bus interface and indicates the status of the room using multi-LEDs.

C Contemplated Access Control Inputs

C.1 Numeric Coded Lock

The lock can have individual codes with up to 8 digits; however, the Numeric Coded Lock can also open the door with a maximum of two linked numerical codes, ensuring the four-eyes principle: the principle states that there is a requirement that two individuals approve some action before it can be taken. This ensures high security standards.

This lock has a direct connection to the CMC and/or the Access Control, which allows the Management of authorisations via the CMC system or the IoT interface. One reader system may be used for multiple handles, provided they are linked to the same CMC system or IoT interface. It also includes an Optical (LED) and acoustic (alarm sound) status display.

C.2 Unique Key

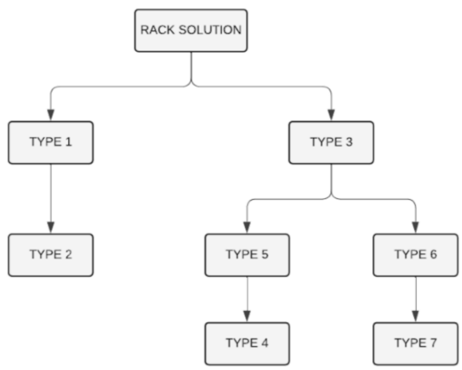
A special mould is generated, being both personal and non-transferable, for the client. This creates a key for exclusive use for the locks present in the Racks under the client´s jurisdiction. The only person trained and authorised to make copies of the key is the customer. A standard key cannot access the equipment held within the lock.

C.3 RFID Card Reader (Transponder Reader)

The RFID lock opens with the use of authorised key cards; however, the RFID Card Reader can also be opened with a maximum of two key cards, ensuring the four-eyes principle. This lock has a direct connection to the CMC III and/or the Access Control, which allows the Management of authorisations via the CMC III system, the IoT interface or RiZone.

One reader system may be used for multiple handles, provided they are linked to the same CMC system or IoT interface. It also includes an Optical (LED) and acoustic (alarm sound) status display.

D RACK TYPES



Appendix. Fig. 1. Tree representing the evolution and construction of the different Rack Types showcased to the client.

As a way to be able to showcase the different solutions to both the client and you, the reader, I decided to map the process with the below Figure [Appendix. Fig. 1]. By doing so, I would have visual support to both explain and show the different templates/types or Rack born from the needs and feedback from the client. The numbering does not reflect the order in which they were created, instead, they reflect the order of similar attributes and characteristics they share.

And such, the Type 2 is created based on the feedback received from the Type 1. Likewise, Type 5 and Type 6 are both created based on the feedback received on Type 3, etc. You will find more details about the design choices and characteristics in the points that are to follow

Regarding the access control, they all share the same input: a unique key, as requested by the client. This includes all the Types except Type 6 and Type 7, which have an RFID Card Reader.

D.1 Type 1

Components:

- 1 VX IT Rack Dimensions: 800 x 1200(24U) x 800mm (W x H x D)
- 1 Blue e+ cooling unit roof mounted 1,6kW
- 1 IoT Interface with 2 temperature/humidity +1 leakage sensor, 1 I/O unit
- 1 Access control to front and rear doors
- 1 DET-AC fire detection and extinguish system
- 2 PDU Switched 1 phase 32A
- 1 UPS 1 phase 2kVA

This first type is the most basic one, made for offices and clean industrial environments. It is a 24U Rack, with a roof mounted cooling unit (1,6kW). One of its strong points is that the cooling unit is "Plug and Play", which means that it does not require complex installation or adaptation of any pipes and drains. It includes a temperature sensor, a humidity sensor and a leakage sensor. They constantly check that the cooling unit is working correctly: the temperature one informs us if the cooling unit stopped or is malfunctioning, as the equipment inside the Rack, with high temperatures, can get damaged. The humidity and the leakage sensors check if the cooling unit is losing water and, as it is in the Rack's roof, the water will go down, affecting the equipment inside.

It also includes two PDUs to allow redundancy: if one of them were to shut/break down, the other one would take its place. That way, the Rack would continue working as normal. They are both switched so that they allow its own monitorisation. This Type 1 does not include a CMC as the number of sensors is inferior to eight. It includes a 2kVA UPS so, in case of a power cut, the Rack can function normally. It also presents a key access control and a fire detection and extinguishing system.

D.2 Type 2

Components:

- 1 VX IT Rack Dimensions: 800 x 2000(42U) x 1200mm (W x H x D)
- 1 Blue e+ cooling unit rear door mounted 3kW
- 1 IoT Interface with 2 temperature/humidity +1 leakage sensor, 1 I/O unit
- 1 Access control to front and rear doors
- 1 DET-AC fire detection and extinguish system
- 2 PDU Switched 32 1 phase 24 C13 4 C19
- 1 UPS 1 phase 3kVA

This type is the direct evolution of the previous type: It is bigger and allows for more climate power. The Type 2 was created based on the client's feedback. They had some offices that were bigger, there were more people working there and/or it was close to a production area. And such, I had to almost double the height of the Rack, from 24U to 42U.

The power of the cooling units also had to be increased from 2kVA to 3kVA. In this case, however, it is not a roof mounted unit, but a door mounted. The size of the roof unit limits its own size and the power it can bring. So, I had to find an alternative: the door mounted one. This still allows the "Plug and Play" scheme, so no further complications arise with its installations. I maintained the other parameter.

D.3 Type 3

Components:

- 1 VX IT Rack Dimensions: 800 x 2000(42U) x 1200mm (W x H x D)
- 1 LCU DX 3kW with 2 outdoor condensers
- 1 CMC system w/ 2 temperature/humidity + 1 leakage sensor, 1 I/O unit
- 1 Access control to front and rear doors
- 1 DET-AC fire detection and extinguish system
- 2 PDU Switched 32A 1 phase 24 C13 and 4 C19
- 1 UPS 1 phase 3kVA

This type was proposed to the client for both offices and data centre environments, however, the latter was not necessary as the client made clear that the data centre rooms were in good condition and there was no intention of modifying them. Then, the Type 3 is not for hazardous locations. It is a 42U Rack, with two temperature sensors, two humidity sensors and one leakage sensor. This time around, the cooling unit does not support "Plug and Play", and thus, needs the installation of a refrigerated pipe towards the two outdoor condensers. It has two outdoor condensers as a way of redundancy.

After the feedback from the client, I decided to include a CMC unit to satisfy the possible need to extend the components that would need monitorization, as the client told me that they were thinking of enlarging some offices. The rest of the parameters (PDUs, UPS, Access Control and Fire Detection) have not changed.

D.4 Type 4

Components:

- 2 VX IT Rack Dimensions: 800 x 2000(42U) x 1200mm (W x H x D)
- 1 LCU DX 3kW with 2 outdoor condensers
- 1 CMC system w/ 2 temperature/humidity + 1 leakage sensor, 1 I/O unit
- 1 Access control to front and rear doors
- 1 DET-AC fire detection and extinguish system
- 4 PDU Switched
- 2 UPS 1 phase 3kVA

The client had not only the intention of creating new offices, but also to merge some of them: their aim is to join some offices which are in the same vicinity. Instead of keeping both the individual Racks that each office may have had, the Racks should also be joined.

The Type 4 is based on the Type 3; however, it is prepared to contain two Racks. It is also necessary to say that this Rack is not prepared for hazardous environments. It contains two 42U Racks with one cooling unit, this means that it has a redundancy of n + 1. The CMC system is necessary in this type, as the PDUs can only control up to eight components. I included four switched PDUs, two for each Rack (redundancy of 2n). Two UPS are also needed, again, one for each Rack.

D.5 Type 5

Components:

- 2 VX IT Rack Dimensions: 800 x 2000(42U) x 1200mm (W x H x D)
- 2 LCU DX 3kW with 2 outdoor condensers
- 1 CMC system w/ 2 temperature/humidity + 2 leakage sensor, 1 I/O unit
- 1 Access control to front and rear doors
- 2 DET-AC fire detection and extinguish system (Master + Slave config.)
- 4 PDU Switched
- 2 UPS 1 phase 3kVA

One of the big factors that drives the client to like or dislike an idea is the economic cost of the solution. The Type 5 was created before the Type 4, also based on the Type 3. However, after being presented this solution, the client decided to "cut" some items: the Type 5 has two cooling units, allowing for a redundancy of 2n. It also has two fire detection and extinguish system, that is due to one of them being the master and the other one being the slave (they present a Master and Slave configuration).

The client, however, said that they do not need/want this type. As such, the Type 5 will not be used and it is only shown here for informative purposes.

D.6 Type 6

Components:

- 1 Micro Data Centre MDC Level E
- 1 VX IT Rack Dimensions: 800 x 2000(42U) x 1200mm (W x H x D)
- 1 LCU DX 3kW with 2 outdoor condensers
- 1 CMC system w/ 2 temperature/humidity + 1 leakage sensor, 1 I/O unit
- 1 Access control to front and rear doors
- 1 DET-AC fire detection and extinguish system Master
- 2 PDU Switched 32A 1 phase 24 C13 and 4 C19
- 1 UPS 1 phase 3kVA

A big part of the client premises are production sides and foundries, as such, some Racks need to be in very perilous and hazardous environments. The client loved the Type 3, and wanted to adapt it so it could withstand the factory/production sides. To be able to do that, a Micro Data Centre MDC Level E was necessary. This is a modular security cell that contains and protects the Rack against external agents.

It is a 42U Rack inside a Micro Data Centre MDC Level

E. It has one cooling unit, which previously requires the installation of a refrigerated pipe towards the two outdoor condensers. I included two temperature sensors, two humidity sensors and one leakage sensor. I also included a CMC system unit to be able to monitor more components. I also included one UPS and two PDUs to allow redundancy: again, if one of them were to shut/break down, the other one would take its place. That way, the Rack would continue working as normal, as it is of the utmost importance that the production does not get affected or interrupted by a Rack failure. The access control used in this Rack will be a RFID Card Reader: it will need two key cards to unlock, following the four-eyes principle.

D.7 Type 7

Components:

- 1 Micro Data Centre MDC Level E
- 1 VX IT Rack Dimensions: 800 x 2000(42U) x 1200mm (W x H x D)
- 2 LCU DX 3kW with 2 outdoor condensers
- 1 CMC system w/ 2 temperature/humidity + 2 leakage sensor, 1 I/O unit
- 1 Access control to front and rear doors
- 1 DET-AC fire detection and extinguish system Master
- 2 PDU Switched 32A 1 phase 24 C14 and 4 C19
- 1 UPS 1 phase 3kVA

Lastly, I will introduce the Type 7. After presenting the client the previous Type, they were enthusiastic about it. As it is needed the maximum level of assurance that the Rack will not, under any circumstances, stop working. That is due to the fact that a stop in the foundry of even some hours, would generate a loss of thousands of euros.

To add an extra layer of assurance and protection, I rescued the concept of the redundancy of 2n with the cooling units.

This time around, the client liked and wanted the idea. So in the Type 7 there are two cooling units. The redundancy of the PDUs and the UPS are maintained. With the rest of the components in place, this becomes the most expensive yet the rightest solution for industrial and hazardous environments. This Type will be used in the most critical instances.