LHC Project Note 298

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Logistic simulation of the transportation of cryomagnets for the LHC project

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Summary

According to the LHC Working Summary Schedule[1], the cryomagnet transportation is scheduled in a given time span: from March 2004 to August 2006. To know whether it is possible to transport approximately 1750 cryomagnets to their specific position in the LHC tunnel within this time period, a discrete-event simulation has been performed. The simulation model aims at showing the feasibility of this within the time frame and with the resources available.

1. Introduction

The transportation of cryomagnets in the LHC tunnel will most likely be a critical activity and should therefore be well planned. The special designed cryomagnet transportation vehicles will have a limited speed and dedicated routes in the tunnel. They will carry the very large and heavy cryomagnets while following a strip painted on the floor of the narrow underground tunnel through an optical guidance system. They will be unable to cross each other except at one point (UJ22). Furthermore, the transportation of cryomagnets can only be performed during the night since other activities will take place in the tunnel during the day. The different sectors of the tunnel will be available for cryomagnet transportation at different time periods due to preceding activities which are scheduled to be completed at different dates. The limited number of vehicles and the fact that the different types of cryomagnets (cryodipoles; arc, DS and MS, SSS and other insertion region cryomagnets) need to be transported by different vehicles increase the importance of carefully scheduling the transportation.

The purpose of this work is to build a model using a discrete-event simulation tool that can decide whether the cryomagnet transportation can be completed with the resources available and within the time limits stated in the Working Summary Schedule[2]. It will also be used to simplify the planning and scheduling of the cryomagnet transportation for people involved in

[1] EDMS No: 90193, rev 4.0
[2] Ibid.

these issues at CERN. This report forms part of the original Master thesis[3] written for this purpose.

When designing such a managerial system it is important to be sure that everything is taken into account and that the outcome of the work fits the purpose. Three levels of detail have to be covered: the strategic level, the tactics level and the operations level. The strategic level concerns the overall strategy foreseen for transporting the cryomagnets in the tunnel. In this case, they are addressed in the LHC Working Summary Schedule[4] where the cryomagnet transportation is attributed a certain time-span. The next level of detail, the tactics, demonstrate that a certain amount of resources is required in order to make the strategy foreseen feasible. In this case a discrete-event simulation has been performed and shows that the cryomagnet transportation can be accomplished with the resources available. The next level, the operations level, is the most detailed one. Here, the scheduling of a short-term period is considered; the exact duration of activities and location of vehicles are displayed.

[3] Lindholm O, Lundgren M: *"Logistic Simulation of the Activities Concerning the Cryo-Magnets at CERN"*, 2002, M.Sc. Thesis. Department of Industrial Management & Logistics, University of Lund, Sweden.
[4] EDMS No: 90193, rev 4.0

2. Present conditions

The calculations are performed in a model built in a simulation tool. A summary of the inputs and output of the underground cryomagnet transportation model is shown in Figure 1.

List of cryomagnets
Location of cryomagnets
Sequence of installation
Availability of infrastructure
Underground routes
Critical transportation resources

→ **Underground cryomagnet transportation model** → **Timetable**

Figure 1: *The inputs and the output for the underground cryomagnet transportation Model.*

2.1. List and Location of cryomagnets and sequence of installation

The overall structure of the underground routes and the layout of the LHC machine through their naming conventions are of importance for the model. As per figure 2, the tunnel consists of 8 different interaction points (IP's).

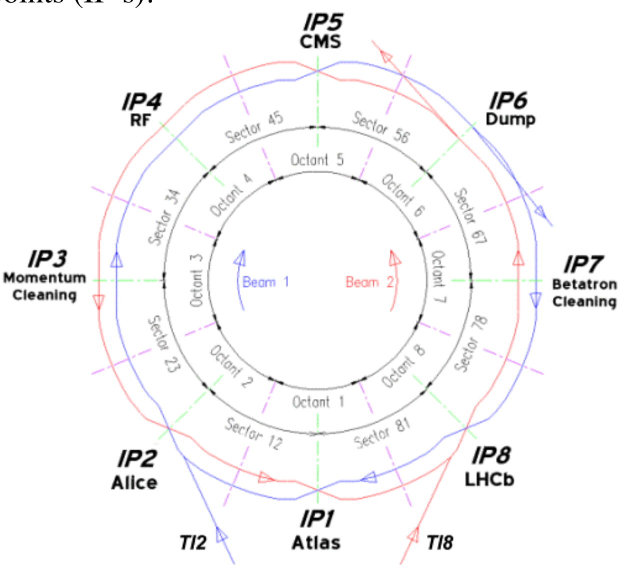

Figure 2: *Overall view of the octants, sectors, IP's and the directions of the beams in the LHC tunnel.*

The beams, travelling in opposite directions are injected in the main ring from the connecting tunnels TI2 and TI8. At point 1, 2, 5 and 8 the beams will collide. The part of the ring between two successive interaction points is called a sector. There 8 sectors in total. For instance, sector 12 is situated between IP1 and IP2 and sector 23 is between IP2 and IP3 and so on. In the same way, there are 8 octants, which unlike the sectors, have an IP as the centre and cover two half sectors, see figure 2.

Each octant consists of two half-arcs, two Dispersion Suppressor areas (DS) and a Long Straight Section (LSS), see figure 3. While the machine is slightly bent in the arcs and DS, it is straight in the LSS. Furthermore in detail, each sector is divided into two half sectors, one on each side of the interaction point. Each half sector is then divided into 34 half-cells and each of them houses up to five cryomagnets depending on the location in the ring. Around interaction points 1, 2, 5 and 8, specially designed cryomagnets are located which are called inner triplets (IT).

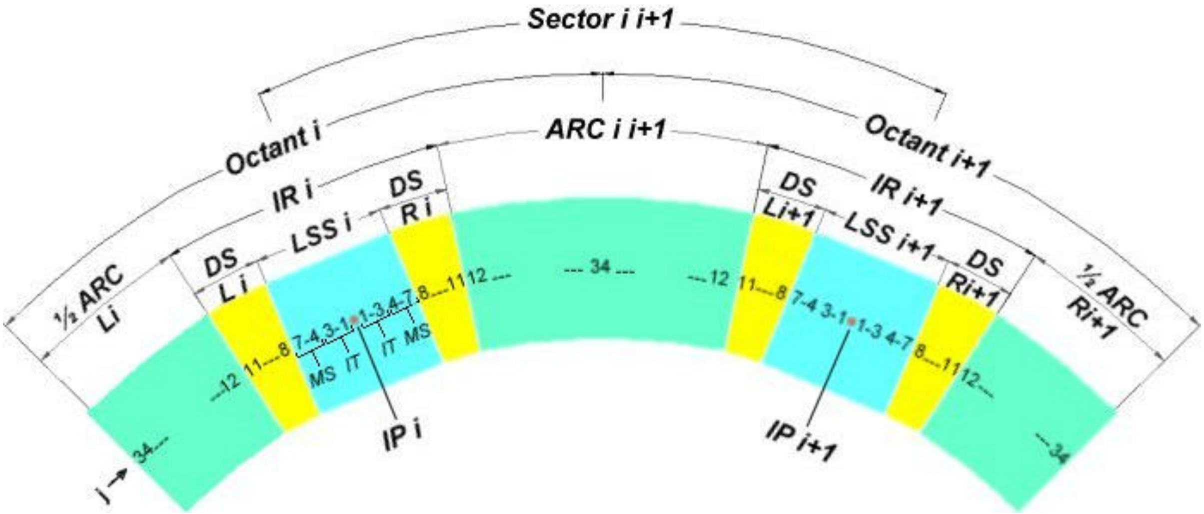

Figure 3: The definition and numbering of a repeatedly occurring part of the LHC main ring.

The total amount of cryomagnets that will be installed is 1746: 1248 are cryodipoles and 498 are SSS and other insertion region cryomagnets. The transportation will proceed in up to four different half sectors at any given moment in time. The reason for this is the limited amount of transfer tables, which are necessary for placing the cryomagnets on their jacks. In total there will be 5 sets[5] of transfer tables available for the cryomagnet installation; one set for each operating half sector plus one extra.

The first magnet to be installed in a sector will be the cryodipole closest to the centre of the sector, i.e. in half-cell 34 in the middle of the arc (see figure 3). The next cryomagnet to be installed will be placed next to the previously installed cryomagnet. The placing of cryomagnets will proceed from the centre of the sector towards the IPs, i.e. from half-cell 34 to half-cell 1. A magnet cannot be installed if the one next to it has not yet been installed (except for the first one of a half sector). This is the case for most of the cryomagnets, they are called Continuous Cryostat cryomagnets (CC). But in some parts of the machine, there will not be any magnets, only the vacuum pipes for the beams. Therefore there will be some cryomagnets, which are standing by themselves, not connected with others. They are called Stand Alone cryomagnets (SA) and can be installed without the previous one being installed. In terms of installation, these places are more flexible and can be utilised when it is not possible to install in other areas. The list and layout of cryomagnets used in the discrete- event simulation model complies with optics v. 6.4.

2.2. Availability of infrastructure

Several activities have to be completed in the tunnel before the cryomagnet transportation can begin. The completion of these activities is scheduled at different dates according to the sectors. Therefore the availability of the infrastructure will allow cryomagnet transportation at

[5] Technical Description for Precision Transfer Tables for LHC Cryo-Magnet Installation, Keith Kershaw February 2001. EDMS No: 304979, Page 4

certain periods in the 8 sectors. As shown in table 1, the first sector (sector 78) will be available in March 2004 and the last (sector 34) in December 2005.

Sector	Available
12	22-Apr-05
23	09-Jul-04
34	09-Dec-05
45	23-Sep-05
56	08-Jul-05
67	04-Feb-05
78	12-Mar-04
81	04-Nov-04

Table 1: *The availability dates for the transportation infrastructure for the different sectors.*[6]

2.3. The underground transportation routes

When the cryomagnets are ready for installation, i.e. they have gone through all preparation and tests at ground level, they will be hooked on to a crane and lowered through the PMI2 pit. The elliptical, approximately 50-meter deep pit is designed to hold the largest magnets and has a width of 18 * 12 m, see figure 4.

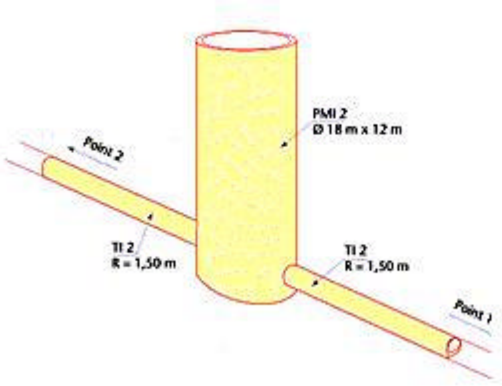

Figure 4: *The elliptical PMI2 pit, which will be used to lower all of the cryomagnets from the surface to the underground tunnel.*[7]

Once a cryomagnet has reached the tunnel it will be put on a cryomagnet transportation vehicle. Only one vehicle can be loaded at any time, which means that the next vehicle will have to wait until the vehicle being loaded has left the loading area. As soon as a vehicle is loaded with a cryomagnet, it starts to travel towards IP2 through the downstream TI2 tunne1, see figure 5. As per figure 5, the main ring has been divided into two halves so work can progress in the two different halves without interfering with each other. At the junction the vehicle can travel either right or left depending on its destination. However, the furthest a vehicle will travel is to IP6.

[6] EDMS No: 102509, rev. 1.4.
[7] http://cernenvironment.cern.ch/Pages/E/Sites/TI2Pgs/TI2under.html

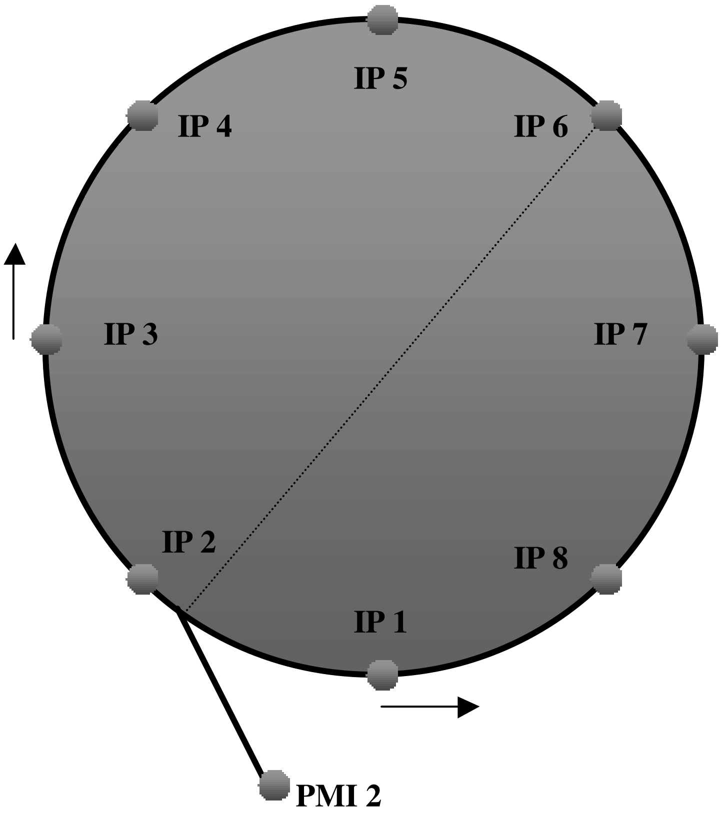

Figure 5: *The LHC main ring with its interaction points. Cryomagnets will be lowered down from ground level at PMI2 and then transported to their specific locations. Note that the main ring has been divided in to two halves to minimise the length of the transportation routes.*

When installation of a cryomagnet is finished, some different requirements have to be fulfilled in order to allow the vehicle to go back to PMI2. Firstly, the route between the current installation point and PMI2 must be free from other vehicles. Secondly, the time must not be later than 05:30 am so as not to interfere with daytime activities taking place in the tunnel. If these requirements are fulfilled, the vehicle can start its return journey. If the time is later than 05:30 am, the vehicle must park at a place in the tunnel where it does not interfere with daytime activities. The most suitable parking places will be close to the IPs (RAs for instance) since there will be more space than in the rest of the tunnel. The installation of the cryomagnets close to the IPs will be postponed in order to save some space for parking in these areas. If the vehicle is parked in the tunnel (near an IP) during the day, it will continue its travel towards PMI2 at 20:30 pm that evening. This will obviously need some vehicle scheduling priorities since vehicles cannot meet in the tunnel except for the junction where the connecting tunnel, TI2, meets the main ring (UJ22). If there are possibilities that one or more vehicles can travel and deliver more than one magnet each night, they will do so without waiting for other vehicles, which might be occupied with a delivery somewhere else in the tunnel.

2.4. The cryomagnet transportation vehicles

Five cryomagnet transport vehicles will be available for the installation. The different properties of the different cryomagnets call for special designs. Since the properties and restrictions of the cryomagnets are different, all vehicles cannot carry all types of magnets. Three of the vehicles are dedicated to only carry cryodipoles and two are only able to carry SSSs and other insertion region cryomagnets.

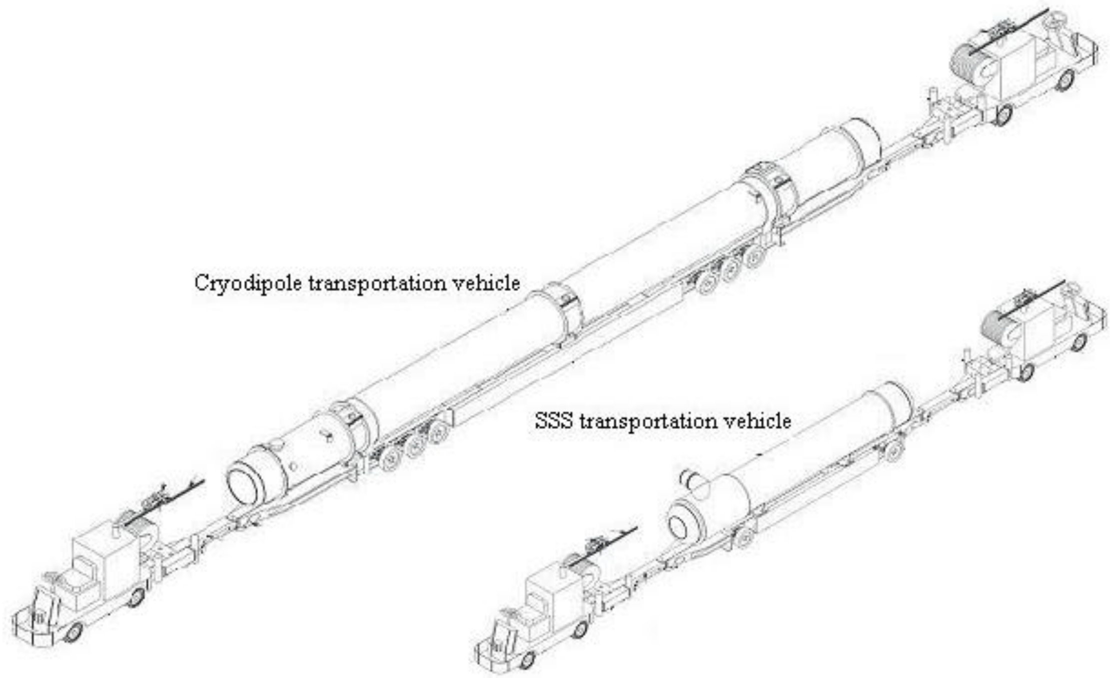

Figure 6: *The cryodipole and SSS transportation vehicle, consisting of two operator-transport-units at each end and one cryomagnet transport unit where the cryomagnet is carried.*[8]

The vehicles have a limited speed of 3 km/h loaded and 4 km/h unloaded when travelling in the tunnel. Among the 8 interaction points, point 1, 2, 5 and 8 have caverns that house particle physics experiments. By-pass galleries are provided around these caverns to allow passage of equipment around the LHC main ring, see figure 7. The transport vehicles will have to travel through those by-pass galleries at a limited speed of 1 km/h.

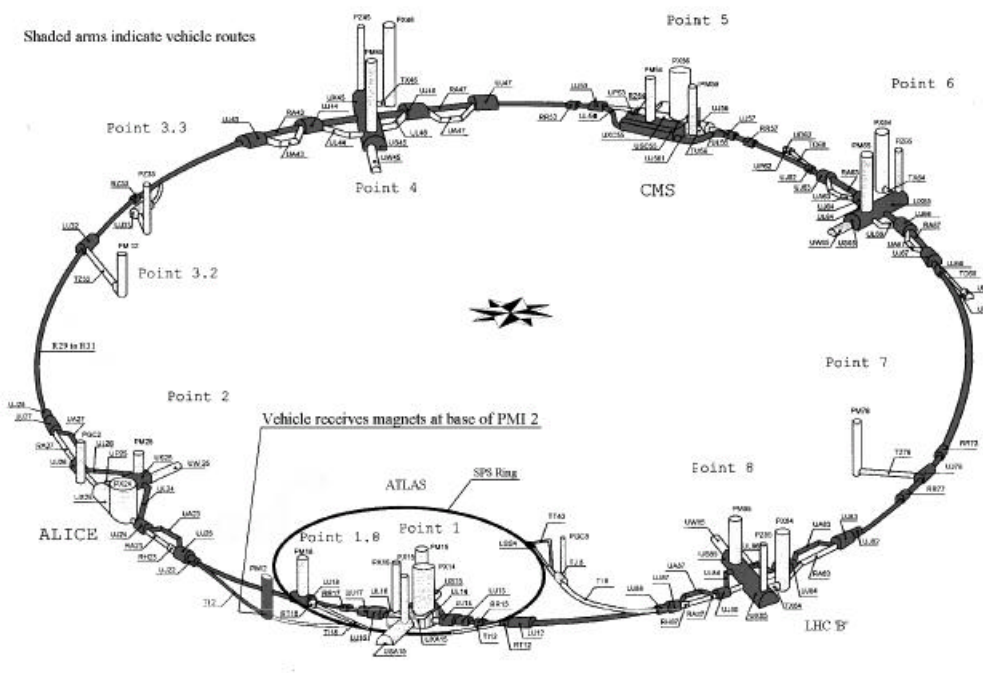

Figure 7: *The shaded arms indicate vehicle routes in the LHC tunnel.*[9]

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[8] Drawing LHCHMUB_0023, LHCHMUB_0025.

2.5. The Placing Procedure[10]

Since it is crucial that the cryomagnets are placed in exactly the right location, specially built sliding tables will be used. The so-called transfer tables will be used to transfer the cryomagnets onto their final supports in the LHC tunnel. As the cryomagnet transportation vehicle reaches its final destination, the cryomagnet is unloaded from the transport vehicle and supported at each end by specially designed unloading equipment. Then the transfer tables take the cryomagnets from the unloading equipment and transfer them sideways onto their final support jacks which will have been pre-aligned by the surveyor. The transfer tables have to move over the concrete tunnel floor surface and be capable of precise movements (precision of 1 mm) vertically and parallel to the plane of the floor. The placing procedure itself has been estimated to take about one hour.

In total there will be five sets of transfer tables operating for the LHC cryomagnet installation. The main requirements for them are load capacities of up to 35 tons, lift heights of up to 120 mm, precise control capabilities in six degrees of freedom, and compact overall dimensions to permit installation of delicate cryomagnets in the restricted space available.

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[9] Technical Specification for the Supply of Cryomagnet Transport Vehicles and Unloading Equipment for the LHC Tunnel, Keith Kershaw July 2000, EDMS No: 111918, Page 48

[10] Technical Description for Precision Transfer Tables for LHC Cryo-Magnet Installation, Keith Kershaw February 2001, EDMS No: 304979, Pages 2-3

3. The simulation model

3.1. The software

Dynamic simulation is today a widely used tool in industry. Dynamic simulation gives the user the availability to predict, modify and optimise results and prevents problems in a chain of events. This obviously leads to simplified planning that saves both money and time and limits problems in organisation and production.

In the early stage of planning the cryomagnet transportation and other logistic activities such as assembly and test procedures for the cryomagnets, a need for a simulation software was seen. After comparing different software packages on the market, AutoMod™ was chosen and purchased. AutoMod had the right level of performance and price along with the fact that the people involved were already familiar with the software.

AutoMod is a Microsoft Windows-based software package developed by Brooks Automation in the United States. The version 10.0 is the one used for the simulations performed. AutoMod is a software package that uses discrete-event simulation. The simulation model represents the components of a system and their interactions. The program evaluates the situation in this system for every single event throughout the whole simulation period. Basically, the model is time based and is executed by performing “runs” and not solved like a mathematical model. AutoMod is mainly a simulation tool for material handling cases and can perform analyses concerning production, warehouse and transportation systems.

The program is built mainly around a user-friendly interface. Depending on the kind of system used and the type of element to be defined, different modules or windows can be opened where situations can be defined. These modules are connected with the source files where the code is written. In most cases when using the AutoMod software, elements are defined in the interface modules and connected in the source file with code. The code is the AutoMod language, specially made for the software, which is quite similar to the Pascal language.

When analysing the model, the AutoStat™ program, which follows the software package, is used. This program allows to perform different analyses and scenarios without interfering with the finished model. AutoStat is a powerful tool that makes it easier to apply the proper statistical sampling techniques to obtain accurately estimated performance of the model under random conditions. Different scenarios such as optimisation, “what if” analysis and sensitivity analysis can be performed here and give much better results than the small statistic module that follows the AutoMod program while running a simulation.

3.2. Model design

When designing the model, AutoMod was not the only software used. In order to feed the simulation model with input data, and to easily display the output, Microsoft Excel™ has been connected. Since this model is based on deterministic input that will not vary during the simulation, the outcome of each run will be the same if the input has not changed. Most of the input is provided via Microsoft Excel, i.e. the data is read from tables into the program during execution. The input not provided through Microsoft Excel is declared in the syntax or defined in the interface. The information that is defined in the interface is changeable, which means that in most cases it can be varied and can then follow any type of distribution. The input that is defined in the syntax is of such a nature that it cannot be changed during the simulation and must be changed in the AutoMod code. All input that does not come from Microsoft Excel is in some way connected to the different graphics, e.g. the speed of the vehicles or the behaviour of the vehicles when travelling in the tunnel. If, for example, one would like to change the time it takes to load or unload a vehicle, it could be easily done in the interface. The duration could then be changed, investigated and optimised by using AutoStat. Since this model is based on non-random input mainly coming from an external source (Microsoft Excel), AutoStat has not been used to perform runs which randomly change during the simulation. Instead different scenarios have been set up and AutoStat has been used to investigate the outcome of every possible combination of variations in a number of critical variables. The general interaction between the model and the other features is displayed in figure 8.

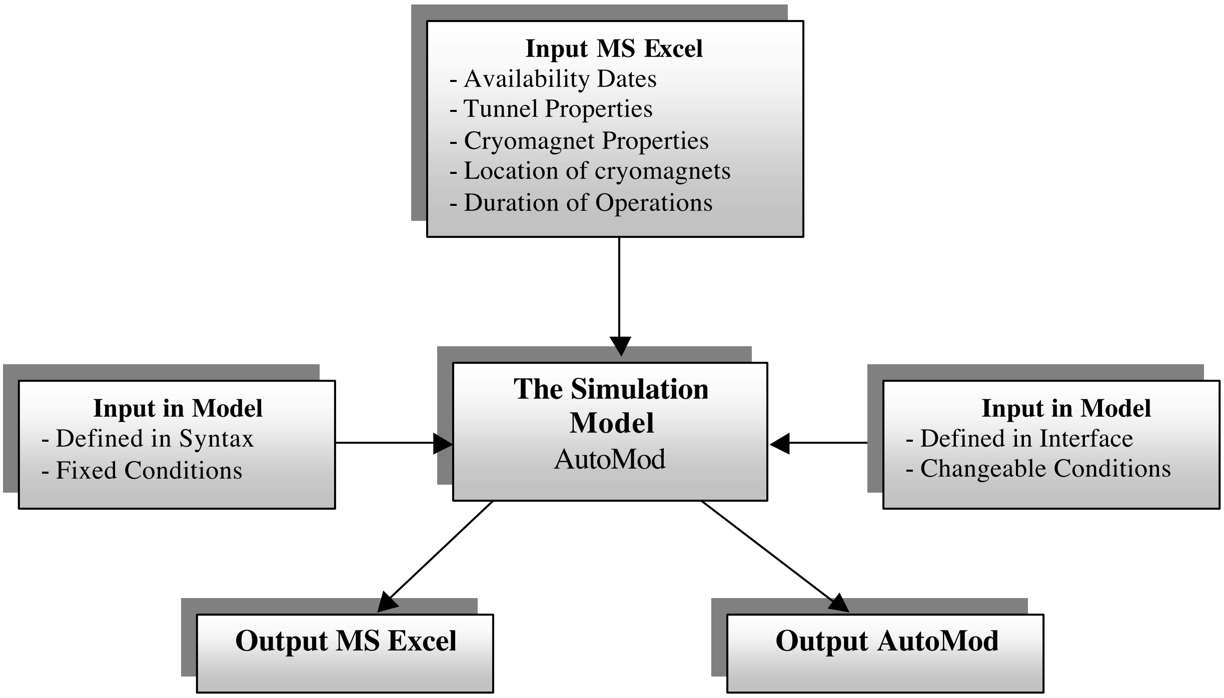

Figure 8: *The overall design of the simulation model.*

3.3. Assumptions

The simulation model covers all activities from the time a cryomagnet is lowered through PMI2 with the crane until it has been transferred to its jacks at its correct place in the tunnel. This means that the activities at ground level, i.e. the final preparations and the warehousing, are not taken into account. Hence, the model assumes that all cryomagnets will be ready for installation and will always be available next to the crane at the PMI2 pit to be lowered at any time. Since the main goal is to obtain a time schedule and show the feasibility of the cryomagnet transportation, activities such as loading and unloading cryomagnets on vehicles and placing cryomagnets in the tunnel have not been described in detail in the model, only assumed to take a certain time. The duration for lowering a cryomagnet through the PMI2 pit is estimated at 40 minutes while lifting the crane will take 15 minutes. The time for loading a vehicle is set at 5 minutes, which makes the total duration for lowering and lifting the crane and loading a vehicle to be 1 hour.

The tunnel that will host the LHC accelerator is not a perfect circle and consists of several by-pass galleries around the interaction points. These by-pass galleries are constructed in different ways to fit to the specific location in the tunnel. Furthermore the different sectors have different properties, which means they vary in length. Since the software is not specialised in order to obtain exact designs or drawings, the layout of the tunnel has been slightly simplified. Even if an exact model of the reality had been obtained, we would not gain very much since the level of detail of the model and the input data is much lower. This assumption has resulted in a model consisting of 16 identical tunnel segments, each corresponding to a half sector, see figure 9.

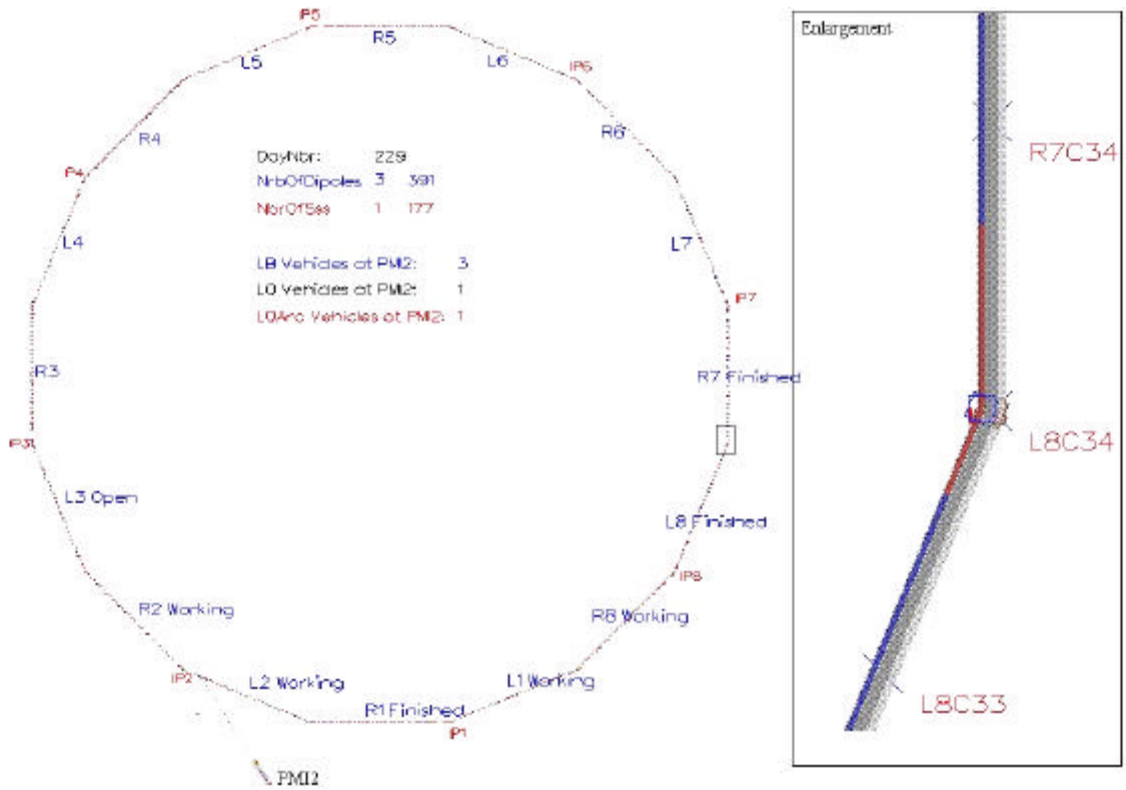

***Figure 9**: An overview of the graphics in the simulation software. The 16 straight half sectors create a polygon instead of a tunnel of bent elements as in the reality. As shown in the enlargement to the right, each half-cell throughout the main ring is defined. For example L8C34 for half-cell number 34 in the half sector left of IP8.*

The 16 straight half sectors create a polygon instead of a tunnel of bend elements as in reality, but this has no effect on the transportation duration. The by-pass galleries that the transport vehicles will have to travel through at five different points (a total distance of 1,6 km) are not included in the model. Clearly this will affect the outcome of the model since the speed of the transport vehicles in the galleries are much lower than in the ordinary tunnel segments. This has been taken into account by calculating an overall assumed speed, where the distance of the by-pass galleries has been compared with the overall circumference and then contributed to a lower speed than the original. This assumption has then been validated by comparing the transport duration from PMI2 to some different points first with the assumption and then with the real values. The point investigated which had the largest difference in transport duration reached 8.7 %. Hence it will take 8.7 % longer time to travel to that point in the model compared to what it would do in reality. This assumption can be defended by the fact that in reality there will always be uncertainties that cannot be scheduled.

Another assumption that has made the design of the model easier is the placing of all the points where the magnets are to be installed. Since the total amount of cryomagnets is 1746, there must be just as many points declared in the model to where the transport vehicles will have to travel. The placing of the magnets in the main ring is not totally identical in each half sector, which means that the distance between the points will vary. To avoid too much unnecessary work which would only result in a too detailed model, the number of installation points has been decreased to 544 (16*34) points each corresponding to a half cell in one of the 16 half sectors (see enlargement in figure 9). The location of the points with respect to each other has been assumed to be the same in each half sector. All half sectors left of an IP follow the exact look of half sector L1 and all those on the right follow the look of R1. Since there can be several cryomagnets placed in one half cell, the distance from PMI2 to these places will be identical in the model but not in reality. However, this will not have a too large effect of the simulation output since the places inside a half cell are normally located next to each other, i.e. most magnets are continuous cryostats and therefore connected to each other.

4. Simulation results

4.1. Cryomagnet transportation schedule

The overall cryomagnet transportation schedule is shown in figure 10. Different coloured fields indicate the status of every half sector throughout the transportation phase. When a sector is occupied by other activities, its status is unavailable. Once the sector becomes available, transportation can start. But both half sectors in a sector cannot start installation at the same time. This is because there will not be sufficient space to have two work teams installing magnets in both half sectors since they will start working at the same location in the tunnel (half-cell 34 in the middle of the arc). The fields with status marked available indicate that the half sectors are available but cryomagnet transportation has not yet started. The lengths of these fields have been optimised in order to fit the schedule to the interconnection works to be performed after the cryomagnet transportation and placing.

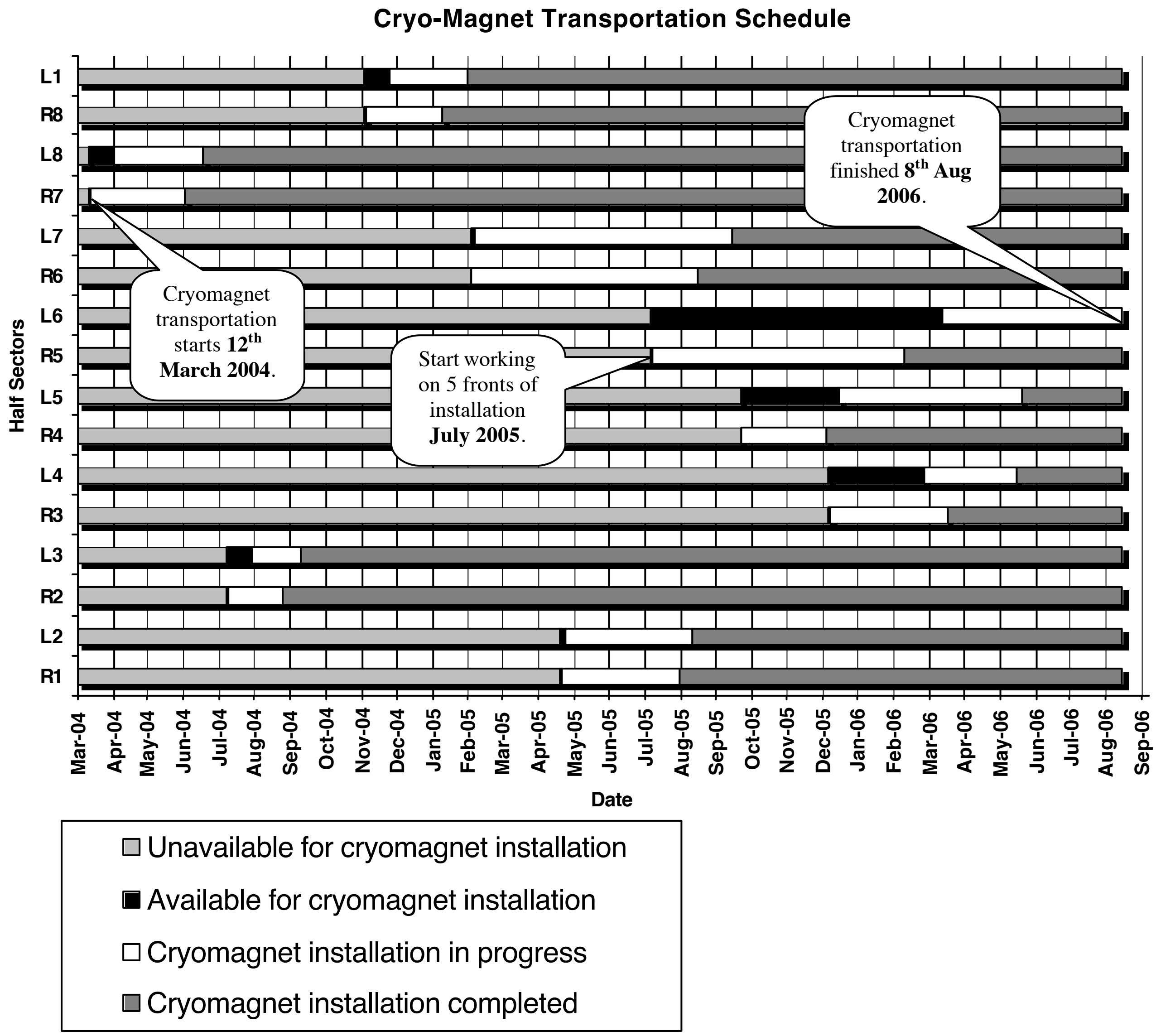

***Figure 10**: The overall cryomagnet transportation schedule.*

The white fields in the chart indicate that cryomagnet transportation is in progress. The differences in durations for different parts of the tunnel depend on the fact that the distance between PMI2 and the sectors vary. Another reason for this is that when transportation is in progress in several different half sectors simultaneously, the installation speed per half sector decreases. The rule for the simulation model has been to have up to 4 half sectors in progress at the same time. But this has been shown to be too few to fit the transportation to the overall installation schedule. It will therefore be necessary to work on 5 fronts of installation starting July 2005. The discrete-event simulation shows that the cryomagnet transportation will finish 17th August 2006, which fits the LHC Working Summary Schedule.

4.2. Duration of transportation

Because of the changing distances from PMI2 to the different half sectors, the transportation vehicles will need different amounts of time to travel to their destination. Hence, the installation duration for the closest half sectors will be much shorter than that for the half sectors located further away. The distribution of the installation duration on the half sectors is presented in figure 11. The half sectors located furthest away: R4, L5, R5, L6 and R6 will take from 5.1 to 7.3 months, while the others will all be finished in less than 3.6 months.

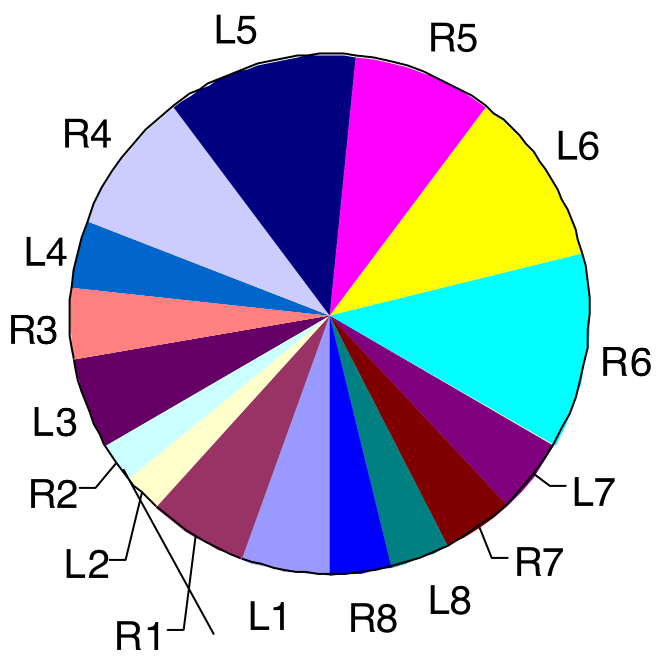

Figure 11: The contribution of each half sector to the total transportation duration.

4.3. Timetable

The simulation model generates an output file containing every cryomagnet in the system, see table 2. Here, the exact location, i.e. half-cell and place in half-cell can be seen. It is also possible to find out the type of cryomagnet and assembly of each cryomagnet, as well as if it is a continuous cryostat, stand alone magnet or an inner triplet.

Location	Place in HalfCell	Type	Assembly	CC/SA/IT	Vehicle	Dep. PMI2	Arr. Installation point
R7C33	1	LQArc	LQOBJ	cc	LQVeh(1)	12 Mar 2004 20:50	13 Mar 2004 0:32
R7C34	1	LQArc	LQOAM	cc	LQVeh(2)	12 Mar 2004 21:50	13 Mar 2004 1:32
R7C34	2	LB	LBARB	cc	LBVeh(1)	12 Mar 2004 22:45	13 Mar 2004 2:26
R7C34	3	LB	LBBRA	cc	LBVeh(2)	12 Mar 2004 23:46	13 Mar 2004 3:27
R7C34	4	LB	LBARA	cc	LBVeh(3)	13 Mar 2004 0:46	13 Mar 2004 4:27
R7C33	2	LB	LBBRC	cc	LBVeh(3)	15 Mar 2004 23:32	16 Mar 2004 3:14
R7C33	3	LB	LBARA	cc	LBVeh(2)	16 Mar 2004 0:19	16 Mar 2004 4:01
R7C32	1	LQArc	LQOAG	cc	LQVeh(2)	16 Mar 2004 23:02	17 Mar 2004 2:46
R7C32	2	LB	LBARB	cc	LBVeh(1)	16 Mar 2004 23:09	17 Mar 2004 2:53
R7C33	4	LB	LBBRA	cc	LBVeh(2)	16 Mar 2004 23:56	17 Mar 2004 3:39
R7C31	1	LQArc	LQOAV	cc	LQVeh(1)	17 Mar 2004 23:01	18 Mar 2004 2:46
R7C32	3	LB	LBBRA	cc	LBVeh(3)	17 Mar 2004 23:07	18 Mar 2004 2:51
R7C32	4	LB	LBARA	cc	LBVeh(2)	17 Mar 2004 23:54	18 Mar 2004 3:38
R7C31	2	LB	LBBRC	cc	LBVeh(1)	18 Mar 2004 23:00	19 Mar 2004 2:45
R7C31	3	LB	LBARA	cc	LBVeh(2)	18 Mar 2004 23:06	19 Mar 2004 2:51
R7C31	4	LB	LBBRA	cc	LBVeh(3)	18 Mar 2004 23:54	19 Mar 2004 3:39
R7C30	1	LQArc	LQOAM	cc	LQVeh(2)	19 Mar 2004 22:56	20 Mar 2004 2:43
R7C30	2	LB	LBARB	cc	LBVeh(3)	19 Mar 2004 23:04	20 Mar 2004 2:51
R7C29	1	LQArc	LQOBF	cc	LQVeh(1)	22 Mar 2004 23:00	23 Mar 2004 2:47

Table 2: *The beginning of the timetable containing the first 20 Cryomagnets to be transported.*

Furthermore, the vehicle that is carrying the magnet and the time of departure from PMI2 is indicated in the list as well as the arrival time at the installation point. Since no crossing is allowed in the tunnel, the vehicle whose destination is furthest away from PMI2 on any given evening/night has to leave first.

The list can be useful since it is now possible to find out which cryomagnets/assemblies are needed for different locations and in which time period these assemblies have to be ready for transportation and installation.

4.4. Summary Installation Schedule

The LHC Project Summary Installation Schedule is displayed in figure 12. The thin bars between the QRL commissioning and the interconnection works indicate the cryomagnet transportation and installation on jacks, i.e. the results from the discrete-event simulation model.

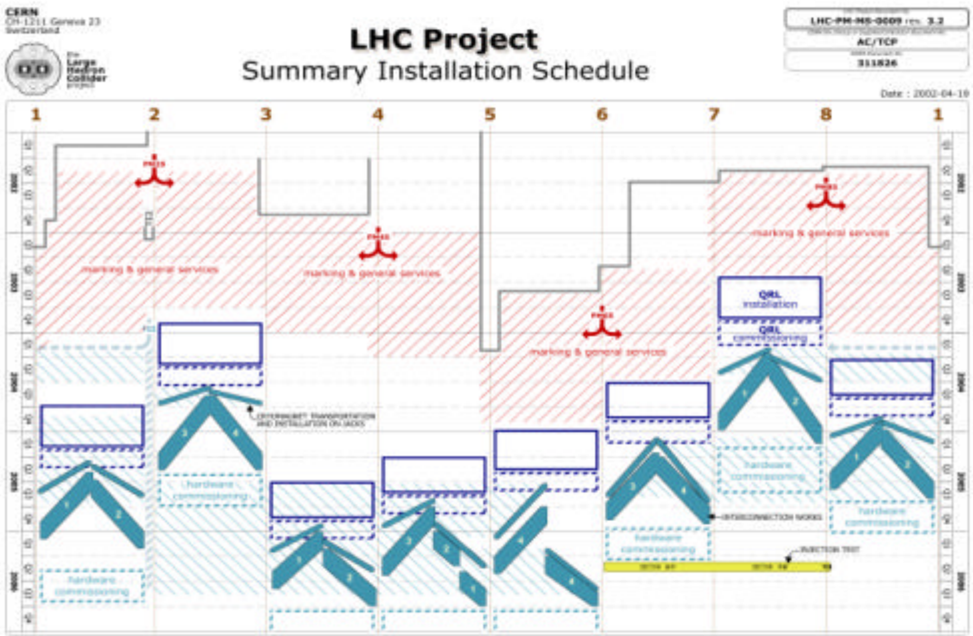

Figure 12: *The Summary Installation Schedule for the LHC Project.*[11]

[11] EDMS No: 90193, rev. 3.2.

5. Operations scheduling

In order to investigate the cryomagnet transportation and installation on jacks even further and in more detail, a short-term schedule must be obtained. Such a schedule is here shown as a proposal of how this could be made in the future. The schedule in figure 13 is based on Linear Scheduling Model (railway-style schedule). The goal is to make sure that the lines indicating vehicles do not cross at any point except at UJ22. In this schedule, three days are investigated, showing which vehicles will carry cryomagnets and to which location in the tunnel.

The horizontal axis shows the tunnel with PMI2 in the middle and IP6 on each side. Arrows in the middle of the chart indicate the lifting and lowering in PMI2. The slope of the vehicles lines are changing, indicating the speed of the vehicles, depending on if they travel through an IP or not. If a vehicle must wait somewhere in the tunnel during the day, it will park in the vicinity of an IP.

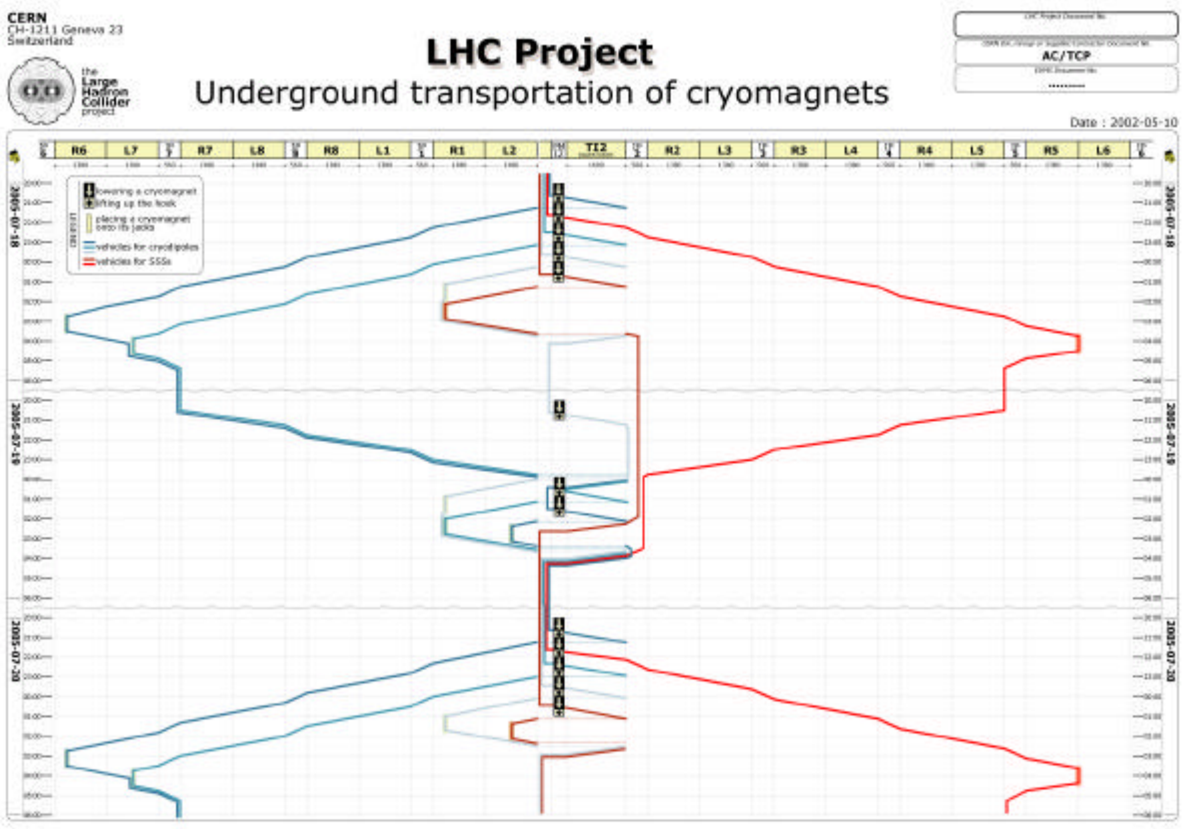

Figure 13: *Short-term detailed schedule based on Linear Scheduling Model covering 3 days of Cryomagnet transportation.*

6. Conclusions

The simulation model shows that it will be feasible to accomplish the cryomagnet transportation in the time span indicated in the LHC Working Summary Schedule with the resources available. But the schedule is quite tight taking into consideration that other activities before and after the cryomagnet transportation have to fit into the schedule. This conclusion shows that CERN has ordered the right amount of transportation vehicles but since the schedule is tight, some time saving changes in the transportation and installation procedure should be carried out.

A remark regarding parking of the vehicles: This issue is not fully optimised in the simulation model. But by obtaining a short-term detailed scheduling analysis, the best parking spots can be found. This is important since the vehicles will otherwise block certain parts of the tunnel, which must be free during the day.

7. References

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