MULTIMODAL TRANSPORT AXIS DESIGN. FORECAST MODEL FOR CROSSOVER SOLUTIONS IN ROAD NETWORK RECONNECTION

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ABSTRACT

An outstanding question owing to design of multimodal transport corridors is related to the resolution of interferences, that appear when different transport axis lay side by side; these interferences arise both between the infrastructures grouped in the corridor and outside it, concerning the reconnection of pre-existing infrastructural and natural networks. During planning and design activities, it seems useful having a tool able to forecast the global impact, due to the resolution of this kind of interferences. This would grant to the design process to proceed accordingly to an efficient use of environmental and economic resources.

Having identified in previous works the different kind of interferences, in the present article a case study of the design of a multimodal corridor, composed of an AV/AC railway and a highway, is analyzed focusing on the resolution of interferences with the local road-network using crossover works.

Starting from an analysis of design solutions, a relationship was identified - expressed in term of intensity - between the solution itself and a set of system variables, representing the corridor layout: geometrical features and number of infrastructures considered, inter-axis, horizontal and vertical alignment, etc. It was also possible to identify a set of parameters, which enable the representation of the impact of the interferences; this parameters were expressed as mathematical functions which were used to create a modelling methodology for measuring and forecasting the intensity of identified interferences.

Finally it was realized a tool that represents a practical support for stakeholders and designers, conceived to minimize the global burden for multimodal corridors; it can also be used to make adequate choices in terms of layout and position on territory of corridors themselves.

Keywords: multimodal corridor, forecast model, over-passing structures

1. INTRODUCTION

Planning, design and rehabilitation of linear transportation infrastructures (considered as singular axis or multimodal corridors) interfering each other have recently highlighted a great quantity of critical matters that previously could be identified only in a qualitative way. In fact there were not any available data concerning causes, intensity and suitable technical solutions.

In previous works it was highlighted how during the design process of multimodal corridors, it was necessary to cope with interferences related to corridor layout.

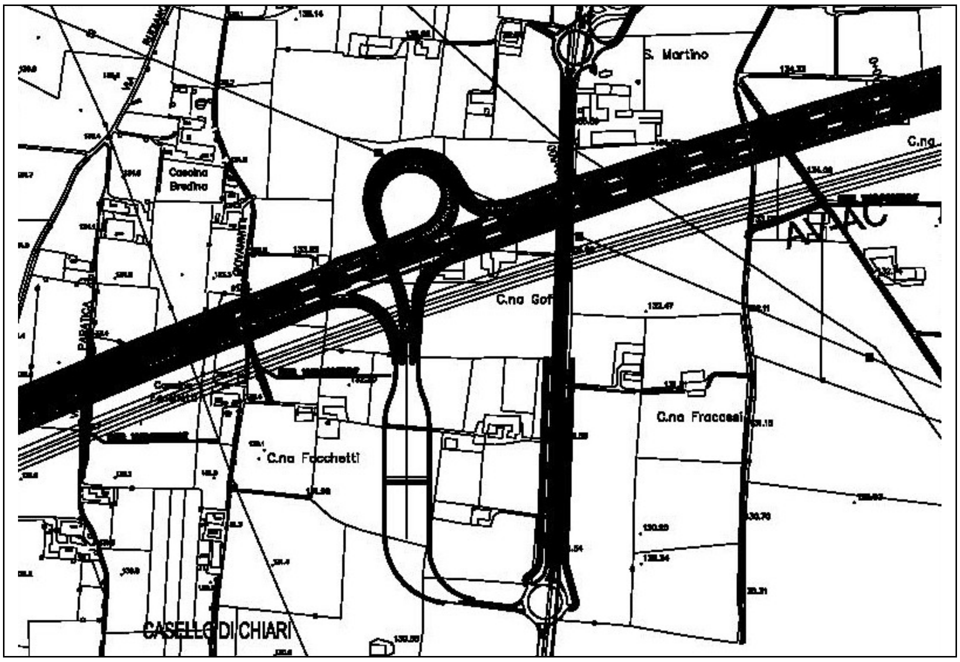


Figure 1: interferences in multimodal corridor

These interferences have been analyzed in qualitative terms in a previous work [CAPRA A., GIUFFRE' T., RINELLI S. (2005), "Multimodal Transport Axis Design. Analysis Of Critical Matters Depending On Railway-Motorway Closeness" - *Proceedings of 3rd International SIIV Congress*]; they can be classified in two main groups: those generated by the infrastructures composing the corridor (for example inter-closed areas, auxiliary and service areas, problems due to safety of circulation) and those generated by the corridor towards the infrastructure network and the natural environment (for example reconnection of existing transportation and hydraulic networks, links to intermediate road network).

The practical experience in corridors design showed that the resolution of these interferences had to involve a great amount of costs, in terms of resources consuming not only economical but also in terms of land use and environment. In certain cases the amount of those costs, initially not measurable, had became significant in relation to the realization cost of the linear infrastructures composing the corridor.

Another facet arisen was that interferences intensity, and consequently the burdens of their realization, was somehow related to the kind of corridor considered, to its layout and to its position on territory.

So, linking all the above factors, a model tool was required that could correctly quantify the intensity of interferences and realization burdens since the planning and design phase, with the following aim: set the best position and configuration of the corridor which lead to minimize the intensity of interferences, estimating also resources to be allocated and assessing the corridor feasibility and other design solutions.

The aim of the present article is to introduce the model conceived by the authors for estimation and quantification of interferences in the multimodal corridors and the mathematic methodology that led to its definition.

For this purpose, the authors had to understand in details the causes of interferences generation and to observe, in a quantitative manner, their behaviour related to the corridor type: only after these preliminary phase, numeric and analytic data were obtained, useful to implement the model itself. The tool obtained is therefore made up by a procedural stage, related to study and data collection methodology, and by a merely model stage for the forecast mathematic tool implementation. The aim of this partition is to supply a problem approach the more general as possible, that separate results from the case study context.

1.1 The Case Study

Seen the above preliminary remarks, in the very beginning it was established, through the qualitative analysis of the real case of the AV/AC Railway Line and the Milan-Turin Highway, that the interferences behaviour in terms of intensity was related to some causes as here summarized:

1) The linear infrastructures type to be put side by side (for example: highways, railways, streams etc.).
2) The territory context to be crossed (for example: geomorphology and urbanization).
3) The overall layout related to the position of each infrastructure inside the corridor (for example: infrastructure inter-axis, horizontal alignment, elevation related to the ground and between the infrastructures etc.).

First step for modelling was to structure a simulation environment, regulated by the above causes. Therefore it was required to define a case study to prepare the essential data set to conduct a sensitive analysis; at the same time it was necessary to avoid that the adoption of a specific case study could be , for its intrinsic characteristics, a limit in opposition to the idea of model. As described below, the case study and its structure represent one of the available configurations inside a simulation environment ruled by the factors above, so that the method used and the output can be generalized to every kind of corridor, land context, lay-out and so on.

Since it was necessary to have starting data for methodology setting and for comparison between simulation and real cases, the authors set the simulation environment basing it on the Italian multimodal corridor context: They considered an AV/AC railway close to an highway, setting the boundary environment as simple as possible, trying to study the behaviour of the corridor related to the minimum number of parameters and leaving the increase of model complexity to following phases. This was made to understand the variability of every single factor, ignoring every overlapping of effects that would make this analysis quite impossible and incomplete. The configuration adopted was:

Multimodal corridor in flat terrain, composed by two linear infrastructures laying side by side:

1) Highway: class A inter-urban highway (DM 5/11/2001), minimum total width 32.50 m

2) High Speed Railway, minimum total width 14.90 m

Concerning layout factors, they will be introduced in the paragraph relative to database creation and sensitivity analysis.

Once the simulation context is set, the analysis was restricted to a single type of interference between the corridor and the other external entities. In this case also, a very frequent event has been chosen: the restoring of links on existing transportation network. Among the possible solutions for the interference resolution, the over-passing solution of both infrastructures by a road of class C1 (DM 5/11/2001) has been chosen; in this way, all the design parameters have been chosen in accordance to law (design speed, grades, radii, etc.). As shown below, the choice of this particular case has not been a limit for the creation of an overall model.

The following schema illustrates the logical process that lead to the set up of the work using the adopted methodology.

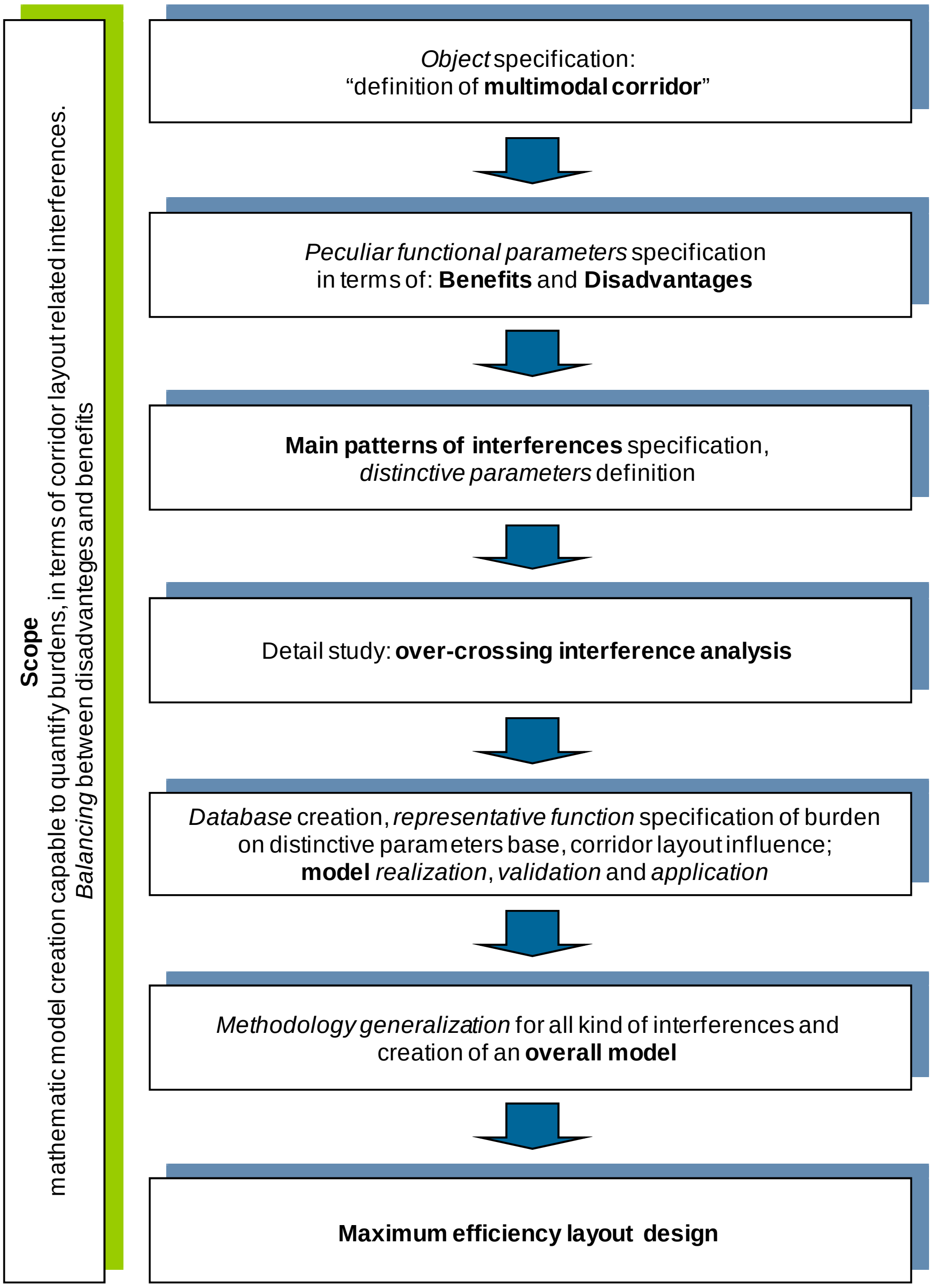


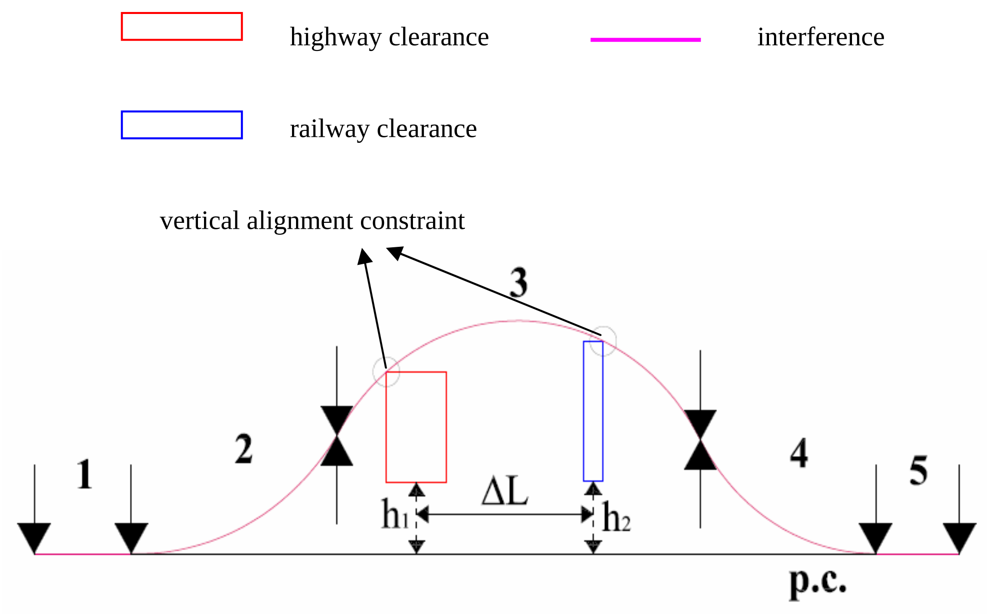
Figure 2: work-flow

2. DESIGN PARAMETERS AND SENSITIVITY ANALYSIS

Once the specific type of interference and the relative methodology of resolution have been chosen, the dependence from the corridor layout set in the simulation environment has been analysed in detail. The analysis lead to the conclusion that interference behaviour depends mainly on the following factors representative of corridor layout:

1) **Inter-axis** AV/AC Railway - Highway
2) **Elevation on ground level** of the two infrastructures
3) **Relative Elevation** between the two alignments
4) **Section Type** considered for the two infrastructures

This is the typical scheme considered for the resolution of the interference between the corridor and a road using an over-passing structure



According to the logical process described above, the system variables have been identified. From these functions representing the burdens connected to interference resolution depend. Referring to the figure above, variables are:

- **h_1**, highway elevation on ground level

- **h_2**, railway elevation on ground level
- **ΔL**, inter-axis between linear infrastructures composing the corridor

For these parameters a range of variability has been fixed; from this range, operating in discontinuous intervals, data have been extracted necessary to create the database for the sensitivity analysis. Considering the target of a corridor design, for the system variables the following ranges have been chosen:

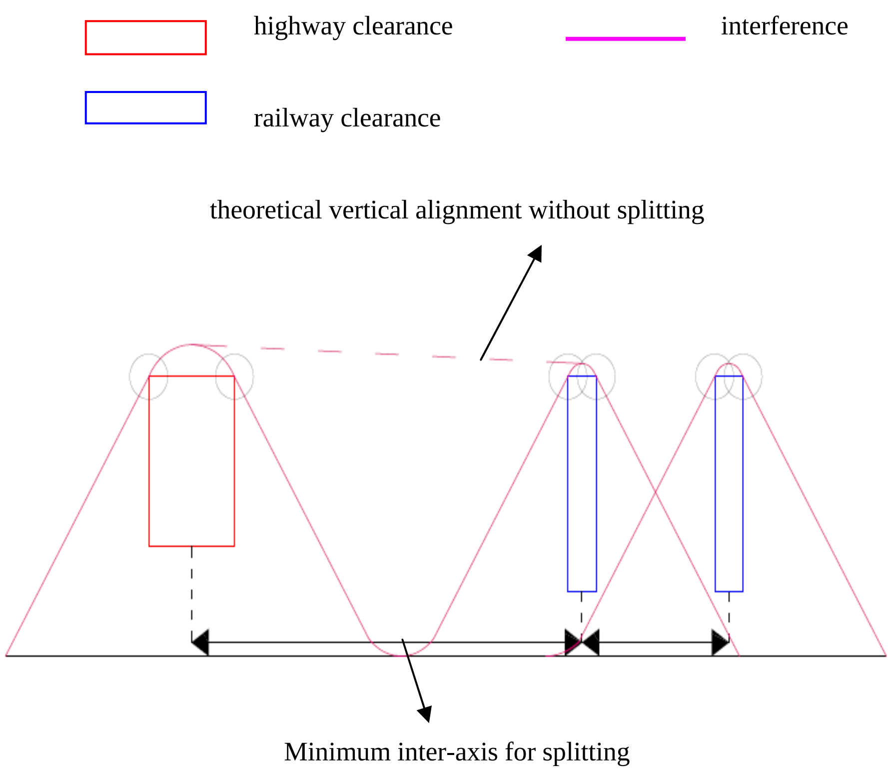
- variable h_1: **$-5\text{ m} < h_1 < +8\text{ m}$**
- variable h_2: **$-5\text{ m} < h_2 < +8\text{ m}$**
- variable ΔL: **$\Delta L > 30\text{ m}$**

The bounds for infrastructures elevation represent the discontinuity points where the change of design solution is the most logical solution (i.e. it is more convenient to realize a structure under-passing the corridor instead of a bridge over-passing it).

The lower limit for the inter-axis depends on the minimum distance necessary to realize the complete cross sections for both the infrastructures, increased by the space necessary to provide the corridor with safety systems.

Before that this lower bound in the existence field of the ΔL variable was fixed, an analysis was conducted about another particular case, in which a crossover above only one linear infrastructure was considered. There were two main targets in this choice. The first one was to analyze the behaviour of crossovers above single infrastructures, for example railways or highways considered separately. The second one was to observe the phenomenon in case of degenerated corridors, that is a particular layout assumed when the infrastructure in the corridor are coaxially overlapping. This single case study allowed also a reduction in the number of variables considered defining the layout, reducing variability to only one dimension: that is to say the one imposed by the clearance of the higher infrastructure considered. The results found here are the same, in terms of behaviours, as in more complex configurations, where all variables are involved. This fact demonstrates that, even if the layout description involves a greater number of parameters, its behaviour depends on them only in terms of a sum of the single effects derived from every single aspect considered. In this way the mathematical representation of the phenomenon is preserved and justified; moreover it could be decomposed and analyzed only on a single aspect at a time, increasing possibilities to understand the results obtained from the modelling from their origins.

A priori it is not possible to identify a maximum inter-axis beyond which we cannot talk about multimodal corridor anymore. In the case study a singular point has been identified where the inter-axis is large enough to split in two different parts the over-passing work, considering the two infrastructures separately, as shown in following schema:



However, this value depends on h1 and h2 and it must be manually detected for iteration and, after the sensitivity analysis, it will be implemented inside the model as a mathematical function.

Once established what the interference intensity depends on, it has been quantified - through a set of parameters that make it useful for economical analysis, multi-criteria analysis and for planning use - representing the full use of resources connected to the resolution.

Trying to cover the maximum number of results, the following representative functions have been identified:

- **Length of resolution [Lint]**: enables, knowing also the length of structures and earthworks area, to measure how much land has to be used, estimating the costs linked to the linear extension of the resolution (i.e. safety barriers)
- **Length of structures [Limp]**: defines how much of the resolution must be realized on over-passing structure (for difference with Lint it gives the length of earthworks). It can be used as a measure of the "complexity" of the structural works, in relation to the technological solution used (for example concrete or steel structure). The complexity of this function can be increased identifying a sort of

relationship between the length of the two types of structure in case of mixed structure (pre stressed concrete and steel).

- **Land occupancy [Occ]**: describes the space necessary for the realization of the over-passing resolution, considering also the shadow of structural works, that usually extends beyond the corridor limits. It can be used, other than to measure the areas' need, to identify - with earthworks volume – the impact on territory due to the presence of the over-passing resolution.
- **Earthworks volume [Mov]**: quantity of materials that has to be acquired, moved and immobilized. It can be used to measure – with land occupancy – the visual impact of the work.

Once the independent variables and the dependent ones (representative functions) were defined a database has been created using the values assumed by the functions at the variation of the system variables inside their domain. These data have been evaluated through manual design tasks. A large number (about five hundred) of over-passing roads was analyzed, setting in each case the design corridor in the layout conditions imposed by the variables identified for the representative functions. The steps adopted for the analysis were 10 meters for the inter-axis and 1 meter for railway and highway elevation. In this way it has been possible to interpolate all the obtained data and move from a discrete/empiric scheme to continue/rational mathematical functions.

Apart from the shape of the functions analyzed, it has been observed a regular dependency between the system variables and the representative functions; it is possible therefore to create a mathematical model, achieving the possibility to create a forecast and quantification tool of the interferences resolution. Here after, as an example, some data are reported obtained for two representative functions in some configurations included in the domain of the system variables.

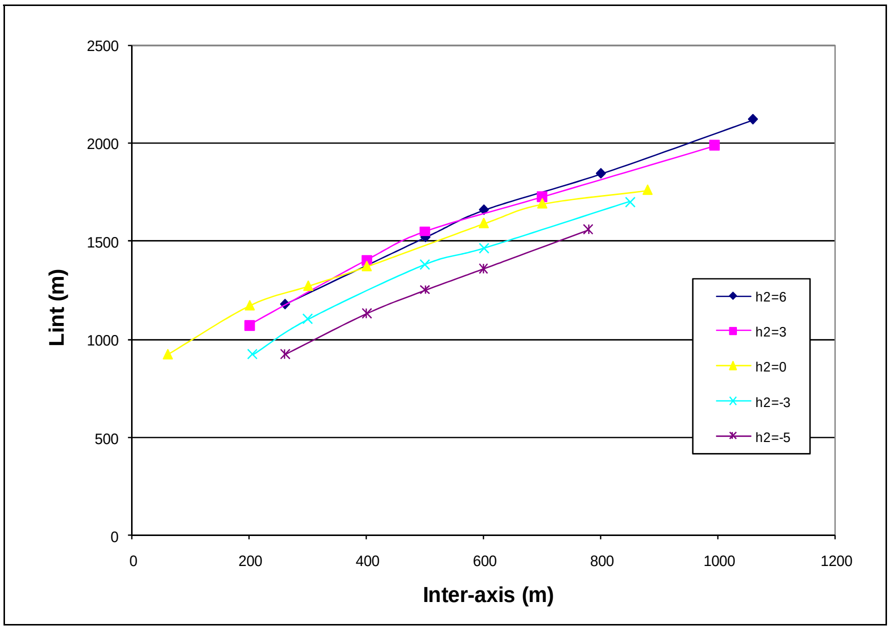


Figure 3: Function Lint for h_1 = 3 m fixed, h_2 = var, ΔL = var

In a similar way, another function in different conditions was represented by:

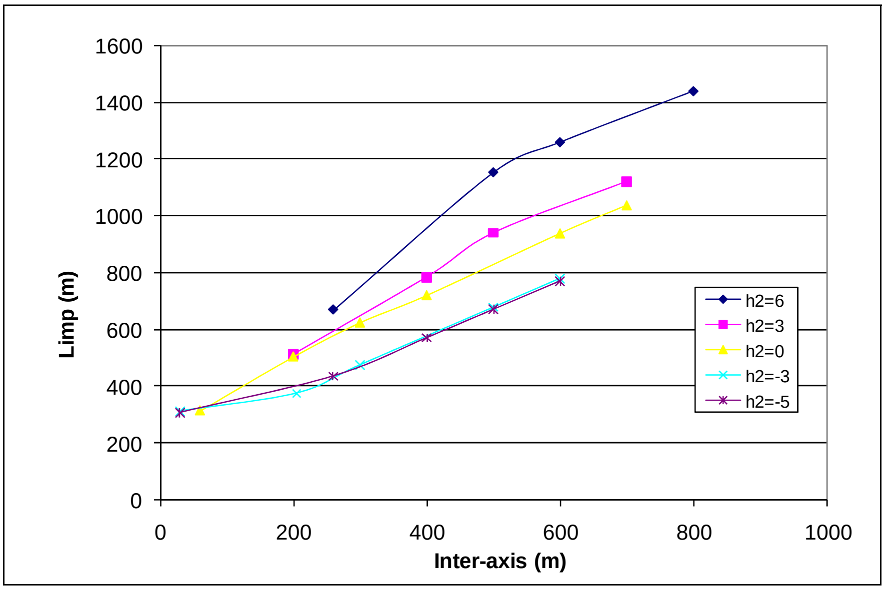


Figure 4: Function Limp for h1 = 3 m fixed, h2 = var, ΔL = var

Each of this graphs was a representation of data manually obtained, as previously described, and filled in the database, aggregating them in sets identified by the same discrete value of the system variables, for example:

Table 1 - Function Limp for h_1 = 3 m fixed, h_2 = var, ΔL = var

h_2 = 6 m		h_2 = 3 m		h_2 = 0 m		h_2 = -3 m		h_2 = -5 m	
ΔL (m)	Limp (m)	ΔL (m)	Limp (m)	ΔL (m)	Limp (m)	ΔL (m)	Limp (m)	ΔL (m)	Limp (m)
260	670	**200**	512	**60**	314	**30**	311	**30**	306
500	1154	**400**	784	**200**	504	**205**	375	**260**	435
600	1260	**500**	939	**300**	624	**300**	475	**400**	570
800	1440	**700**	1120	**400**	720	**500**	679	**500**	670

It can be observed that similar results, in terms of behaviour regularity, can be found in all the configurations analyzed for each representative function; this regularity is significant in every single case, being a widespread phenomenon and not associated to a particular case study or particular point in the creation of the database.

Through the database creation, the conclusion has been reached that interferences behaviour can be schematized, using the obtained data, in a mathematical model that describes in a continuous way the behaviour of the representative functions.

3. MODELLING AND VALIDATION OF RESULTS

Starting from the data obtained creating the database and the observations about the behaviour of the functions linked to them, the authors could proceed to the next step in interferences treatment associated to the presence of a multimodal corridor. With the creation of the database the authors were able to identify all the possible conditions in which a crossover work can be shaped in relation to the presence of the multimodal corridor. During data analysis an important finding arose: the found out data present a high regularity in their behaviour, thing never observed before. So all the collected data could be used as an abacus, representing a sort of simplified forecasting model. Manually comparing the values obtained from several analyses, with a clearly iterative process, it would be possible to have immediately a certain number of results. However, it has been emphasized how the behaviour of the functions is so regular to be performable through interpolating mathematical functions:

- Lint = f (h_1, h_2, ΔL)
- Limp = f(h_1, h_2, ΔL)
- Mov = f(h_1, h_2, ΔL)
- Occ = f(h_1, h_2, ΔL)

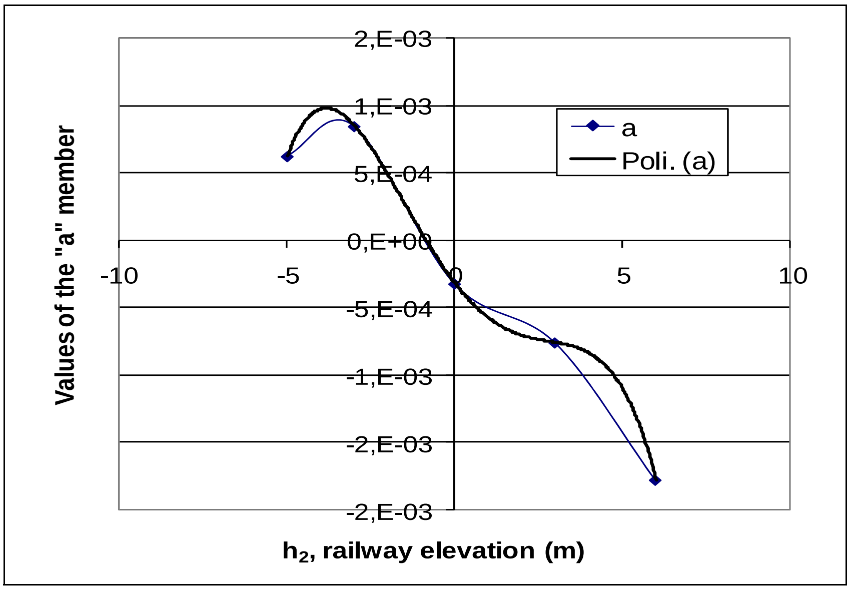
This fact itself would concur to pass from a discontinuous model to a continuous one, through the interpolations among functions, related to the system variables previously determined; once formulated the mathematical expressions of the functions, it would be quite simple to translate them in a calculator language, in order to deal with them with all the related advantages: tool ease of handling, modelling process automation, determination of minimum and maximum points. In order to go on in this way it is necessary to pass passage from the discontinuous outline of the database to the continuous one proper of the model made with interpolating functions. In a semi-automated way a composite fitting polynomial operation has been put into effect, characterizing those interpolating functions that approximate at best the data in the database, expressed in relation to the values assumed from the corresponding variable; the interpolation in many dimensions, in this case three degrees of variability, has been solved adopting a grating methodology, eventually extendible also to a greater number of dimensions: that obviously would concur consequently to increase the number of unknown quantities previewed for the system and elevating the level of accuracy, in order to allow the simulation to be the most similar to reality, also considering the interferences that have not been analyzed. Adopting in all the cases the polynomial interpolation of the fourth degree, values of R^2 were obtained very close to the unit, confirming the high reliability of the adopted technique. In this way all the functions have been implemented through the grate methodology, according to the following outline:

$$S = f(h_1, h_2, \Delta L)$$

where S stands for the generic function for burdens. It could be also represented in its explicit shape as:

$$S(h_1, h_2, \Delta L) = a((h_1), h_2)*\Delta L^4 + b((h_1), h_2)*\Delta L^3 + c((h_1), h_2)*\Delta L^2 + d((h_1), h_2)*\Delta L + e((h_1), h_2)$$

This means that, at the higher level of the grate, it is possible to see a polynomial function were the members are functions of h_1, h_2 and ΔL themselves. Their expressions were obtained trough polynomial interpolation as in the following example:



$a_1 * h_2^4$	$a_2 * h_2^3$	$a_3 * h_2^2$	$a_4 * h_2$	a_5
-2.34E-06	5.92E-06	6.17E-05	-3.21E-04	-3.21E-04

Figure 5: interpolating equation of the fourth order of the “a” member

This is an intermediate level in the complete, implicit form of functions above indicated. In fact it is possible to see that the variable h_1 is still not considered. This could be done improving a subsequent interpolation of the members a_1, a_2, a_n in the direction of h_1.

The final result, from the mathematical point of view, is, for every function of representation, the creation of one influence hyper-surface in 4 dimensions; as an example, stopping at three-dimensional level, for one of the functions the result can be represented in the following way:

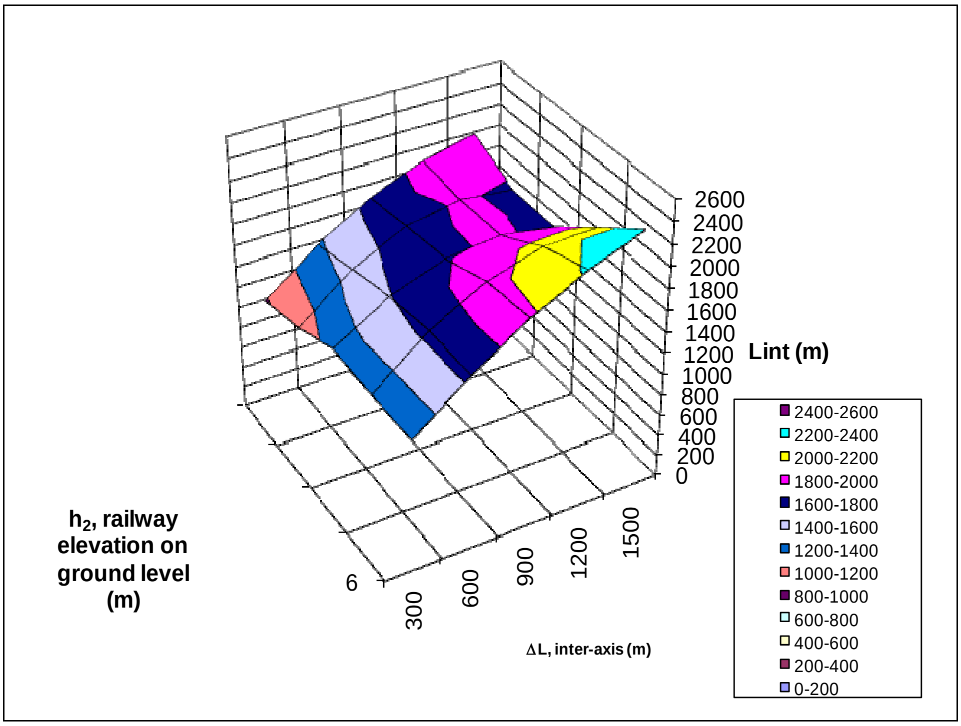


Figure 6: influence surface of Lint(h_2, ΔL) for h_1 = 3 m fixed

Disengaging the only fixed variable, that is connecting n graphics of this kind each other, the hyper-surface above mentioned is obtained. At this point, a system based on a calculator, with inside itself all the interpolation equations, would move on the iper-surface to obtain the results according to the corridor layout defined by the operator. It could moreover establish, through the functional analysis, the points of minimum and maximum for each function, defining the corridor layout achieving the minimization of burdens, taken singularly or in their complex. To check the goodness and reliability of the model, two different analyses have been conducted: the first one regarded the manual planning of crossover works in the model conditions, but using data not included in the creation of database; the second one has been carried out as a comparison with cases of crossover works really designed, whose boundary conditions have been led back to those set up for the model. In the first case the total error was close to 1%, confirming the values of R^2 found out for the interpolated functions. In the second case values were observed essentially in accordance with the model forecasts where the conditions were as coherent as possible with those on which it has been structured the simulation environment. On contrary variations inferior to 10% have been noticed, in case of vertical terrain profile not regular: this matter causes a shift of some meters along the longitudinal profile of the crossover work; higher values of terrain irregularity would be however hardly compatible with the design of a corridor composed by linear infrastructures similar to the ones considered here. Higher shifts in the forecast have been observed for design speed values for the crossover work smaller than the ones in accordance to law and used for creation of the model.

In conclusion the model works effectively with a high degree of reliability whether it is used in conditions similar to the hypotheses on which it has been developed; moving from such hypotheses the forecasts precision decreases, remaining however acceptable when the territory at the boundaries is not perfectly flat, while it would be necessary to implement different modules to consider the design speed amendment; this matter however doesn't represent a limit in an absolute way: the template used for the creation of the model would suggest the introduction of one new variable in order to consider this matter, without impugning the general goodness of the described methodology.

4. POSSIBLE PRACTICAL APPLICATIONS

Theoretically infinite combinations of planning parameters exist within which observing the model versatility. Here after the more interesting cases will be analysed , for subject typology in relation to tool operability and its result. The possibility to arrange data relative to interferences resolution with no need to proceed with the design of them is one of the first advantages; it is therefore possible to use the model for planning activity when the shape and the position of the corridor on the territory are still not defined.

When planning a multimodal corridor the target is to define the layout of linear infrastructures and to minimize the consumption of the resources: this consumption is due in part to the realization of linear infrastructures within the corridor, in part to the interferences that they generate. Supposed that the consumption of resources can be known in relation to the design section adopted, the model can forecast how much the interferences resolution costs. Here after is shown, through some examples, how the problem usually appears, how it can be solved using the model and which are the further possible developments for the model itself.

a) *Free planning/design*: is the case with the maximum degree of possible freedom, it happens when it is asked to design a multimodal corridor without binding conditions at the boundary. A real case in this sense can be the multimodal corridor constituted from AV/AC railway line Milan-Verona and the highway Brescia-Bergamo-Milan, planned and designed at the same time. In this case the only known parameters are the costs. The solution of the problem therefore concern to the highway and railway position in order to minimize realization costs of themselves, consumption of territory and costs related to interferences resolution.

All the following matters have to be taken in: number and type of previewed interferences, length of the corridor; moreover the following fact must be considered: the minimum point of one of the representative functions of the burdens does not correspond to the minimum point for the other functions and generally the minimization of a type of interference does not correspond to the minimization of the others.

This last problem can be easily overtaken with a computer based tool that can carry out a total analysis of all variables for all the interferences, finding step-by-step the best solution in the complex. Having the representation functions, the layout of the corridor can be arranged according to priority given to the saving in interferences resolution or the section of the corridor itself. It can be noticed how the parameters of cost of materials, workings and territory play a determining role and, since they vary from place to place, the model can lead to different solutions even if the target to minimize the consumption of resources is always the same.

This fact however does not have repercussions on the model: it is, for its ideation, free from the monetary value, supplying general geometric parameters that could be converted in other quantities independence of the examined case. That represents an advantage in case of adoption of a “multi-criteria type” choice methodology: in this sense the mathematical values supplied by the model can be converted in generic evaluations that can be weighed in different ways according to stakeholder’s will.

Remembering what has been said about the error committed by the system, an analysis has been taken on real cases of Italian multimodal corridors. This analysis showed that the over-passes were really well-designed owing to the layout locally assumed by the corridor, with a difference from the optimum position of about 1-5%. However this also showed that a better layout configuration of the corridor itself would lead to a saving of about 10% of all resources involved in the resolution of the interferences without a sensible increasing in the cost of the linear infrastructure; in fact it is impossible to analyze this matter and quantify it without a mathematical tool able to find the minimum and maximum positions of the interpolating functions identified in the present work.

b) *Semi-free planning/design*: in this case the designer deals with an “ex novo” design of the corridor infrastructures, although some constraints on adoptable layouts exist. They could be, for example, corridor section constraints. This is why the Stakeholders often require more or less deep cutting sections to minimize the environmental impact. In this case, if the Stakeholder would indicate a depth interval for the cutting sections, it could be established the optimum point for the linear infrastructure layout. This, however, considering also those aspects discussed above. Also in this case, the optimum layout would be achieved through the model.

The model could be developed to support different design solution decision, such as between under-passing and over-passing structures.

c) *Constrained planning/design*: this is the case, not infrequent, of a linear infrastructure already build (for example the highway) and the other to be build later. Examples are the multimodal corridor AV/AC Railway-Highway Milan-Turin and Milan-Bologna.

Some more new and important matters arise further the ones of case a). The insertion of the new infrastructure, within certain inter-axis limits, causes important amendment in junctions, toll areas, over-passing works and service areas.

The inter-axis choice influences the costs of the corridor realization; moreover the actual infrastructure must remain on duty during the construction of the other, with an increase of organization and design complexity. The target is, therefore, to show how the model can support the designer in the definition of the minimum cost solution.

The idea could be to find a combined function: it should include both the railway realization cost, depending from length ad section type, and the burden due to interference resolution, using data from the model, in relation to their number. Finding the minimum of this function, the best configuration will be found.

Another case of constrained design could bind, if there is a small quantity of land available, to keep the two linear infrastructures very close. The opportunity to manage the territory would become more important than the problem of costs analyzed before. If the land deficiency could compromise the realization of the corridor itself and the new strategic infrastructure, it should be accepted to cover all the costs due to excessive closeness of the two infrastructures. In this case, with certain boundaries conditions, it could be possible to operate only in a restricted range for inter-axis, finding however the optimum point.

A consideration apart should be done in case there is complete freedom of choice about inter-axis and about the opportunity to interfere with other works auxiliary to the existing and on duty infrastructure. If this happens where there is land available but expensive, it is possible that the benefits depending from an elevated inter-axis are overridden by expropriation costs for the inter-closed area. It should be compared the optimum point between the best solution for resolution of interferences and the best one relative to land acquisition. The number of variables present is big and any solution is not absolutely the best; the model let simulate the corridor behavior with its peculiar parameters before designing it.

Finally if other interests are present, it can be evaluated if the realization of the corridor is really convenient and really leads benefits to the community.

5. CONCLUSIONS

Experience highlighted benefits connected to multimodal corridor realization, but also revealed how, on the other side, there are some interferences due to the structure of the corridor itself and not divisible from it. This means that the corridor can lead not only benefits but also costs: this two matters have to be weighted in relation to a great amount of identified parameters, classifying at the same time the possible interferences.

The question was whether it was possible to link the interferences intensity and the relative resources consumption with the corridor layout. If it were possible to establish a relationship, it could be possible to design the corridor minimizing the impact of interferences on the total cost of the work.

A single type of interference has been analyzed, the over-passing solution for the reconnection of existing roads: the target was to identify a procedure that can eventually be extended to other types of interferences, in order to find a strategy to be adopted in the implementation of the model for corridor design.

First of all, the functions representative of resources consumption have been identified, in relation to the interference intensity. This functions have been found dependent on a set of system variables, representing the corridor layout. A database has been created in accordance to the hypothesis above and a regular relationship between system variables and functions really exists; moreover this regularity can be mathematically expressed and it is possible to pass from a discontinuous methodology to a continuous model that can be also computerized.

Analyzing functions' behavior, the mathematical model has been implemented using composite polynomial interpolation with grate shape. The computerized tool obtained can help in simulating corridor behavior with relative interferences depending on design parameters set.

The model accuracy has been tested on several cases, theoretical and real, demonstrating the possible use of the tool for the practical design and planning; errors surveyed were lower than 10% depending on the effective condition of application of the model, similar or different to the simulation environment used for tool implementation.

Going ahead on the work, the limits of the model and of its results have been analyzed, evaluating the possible future developments.

Concerning the limits, it came out the need to increase the database arranging a series of independent modules to consider the variation of design speed. Some complications arose from the manual management of system variables used in relation to all those present. From this analysis it has been possible to confirm that the variables chosen were, with a satisfying approximation level, the most representative, paying attention to verify the agreement between model and reality application conditions.

Assuming to meet similar problems also in the resolution of other types of interferences, it let hope for the implementation of other similar models. In this way, the possible evolutions of the methodology have been highlighted: at the first stage, the extension of four-dimensional model for over-passing works to other types of interferences described in the introduction; at the second stage, the integration of different modules to obtain a general model for planning and design of corridor layout.

The structure of data showed how they can be easily treated with computerized procedures; this peculiarity should be utilized for the automation of interpolation, making faster the model implementation even in its most complex configuration and making the database constantly upgradable.

At the last stage it could be utilized the calculator to process the obtained results to find the configuration of variables that realizes the minimum cost. The benefits derived from this system are clear: great number of available plain data and opportunity to treat them easily.

In conclusion the model arranged can be a useful tool for Stakeholders and designers planning and designing infrastructures multimodal corridors.

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The following projects have been used and analyzed during the work:

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