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Mobility and Urban Planning Integration at City-Regional level in the Design of Urban Transport Interchanges (EC FP7 NODES Project – Task 3.2.1.)

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Abstract

NODES is a European Commission R&D project aiming to build a toolbox to support European cities in the design and operation of new or upgraded public transport interchanges. NODES seeks to find the most innovative approaches to key areas in this arena such as design, ICT, management models, energy and environment. The Madrid Transports Consortium (CRTM) has led the work on the topic 'Integrated land use and infrastructure planning' (Task 3.2), which is a long standing mantra for planning policies and proved to be difficult in practice.

This document describes a first section (3.2.1) that focuses on the city-regional scale: a theoretical framework is developed for a further understanding of the question, whereas a first tool is proposed for a complete assessment and diagnosis of the public transport network, urban integration, the relationship with land uses and the strategic role of a node within the whole network. This tool may also enable more prompt detection of areas for intervention and/or investment. Second, a simpler tool can guide a new interchange project by evaluating an array of different scenarios at a city-regional level by a selection of indicators that identify the optimal scenario for interchange performance.

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Keywords: transport interchange ; intermodality ; land use transport integration ; urban environment ; urban integration

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1. Introduction to NODES Project and objectives concerning Land Use-Transport integration: task 3.2.1.

Since 2012, within the 7th Framework Programme, the European Commission has promoted a R&D project called 'NODES': 'New Tools for Design and operation of urban transport interchanges'. NODES team is integrated by 18 partners coming from nine European countries and a diversity of profiles: transport authorities, private operators, research centres, consultants and stakeholder associations. NODES seeks to find the most innovative approaches to key areas in this arena such as design, ICT, management models, energy and environment, so that European cities could benefit of a toolbox to support the design and operation of new or upgraded public transport interchanges.

The Madrid Transports Consortium (CRTM) has led the work on the topic 'Integrated land use and infrastructure planning' (Task 3.2). This is maybe the most problematic field, given that a joint transport and urban planning spills over the regular scope of action of interchange developers, whereas it involves the cooperation and agreement of various authorities. Land use-transport integration is a long-standing mantra for planning policies and proved to be difficult in practice. Therefore, our goal is to conceive a simple but relevant framework that may articulate crucial points of agreement.

This document describes a first section (3.2.1) focused on the city-regional scale: a theoretical framework is developed for a further understanding of the question, whereas a first tool is proposed for a complete assessment and diagnosis of the public transport network, urban integration, the relationship with land uses and the strategic role of a node within the whole network. This tool may also enable more prompt detection of areas for intervention and/or investment. Second, a simpler tool means to guide a new interchange project by evaluating an array of different scenarios (location, modes and connections) at a city-regional level by a selection of indicators that identify the optimal scenario for interchange performance.

2. State of the art and problematic.

Land use-transport interaction is an issue that has remained on the table for decades. Inter-dependences between the two fields are so wide and diverse that the topic can be –and has been– approached in many different ways. A good synthesis on this topic is the work of Wegener and Fürst (1999). This document compiles the variety of disciplinary topics and approaches that the question involves: from the economical and social aspects to the technical approaches, from the 'ideal' systems to the empirical efforts to improve planning practice.

The concept of 'accessibility' by itself is representative about the problematic involved in land use-transport integration and the gap between theory and practice. Accessibility appears as the key concept linking land use and transport systems (Wegener & Fürst, 1999; Batty, 2009). However, as Batty describes, this concept is quick-, richly developed in the academic scientific community without an equivalent implementation into planning practice. This notion is nowadays very difficult to be understood from only one point of analysis, since the theoretical labyrinth has become complex and full of nuances.

So, within the NODES Project, what should be the recommendations for a new interchange? What should be the synthetic factors to be taken into account when it comes to land use and transport planning at a city/regional scale?

This paper discusses the first steps given by NODES project to address this issue in a pragmatic unified way.

3. Mission statement and considerations at a city-regional scale.

At a city-regional scale, many issues could be faced in theory but, first of all, our approach tries to keep the topic contained within transport and urban planning scope of action.

Also, given that we develop these tools for a real, practical implementation, we are aware of possible limitations, depending on each city and planning team.

- Many of them are the result of institutional barriers: transport and urban planning usually are not integrated competencies and they may be the field of action of different scale governments (regional, municipal, etc.) or political competitors, to name a couple of possible situations. That is why we try to develop NODES tools to enhance an agreement on basic, understandable yet valuable standards that could isolate decisions out of the usual political discussion.
- Tools are not designed to reach a unique optimal decision. At an urban-regional level, this is complex to define and not always existing/available. Moreover, authorities must find balanced decisions in order to satisfy multiple priorities. Thus, NODES tools are more focused on informing/supporting the process, by allowing taking strategic decisions once enriched with a more precise knowledge of the current situation, dynamics and potentialities. NODES tools center the debate on objective, innovative, priorities, avoiding more tricky, politicized topics.
- Another important issue is the availability of resources, not only economical, but also human and technological. Four-step transport models are a precedent that we have considered: they are the most accurate, advanced tool for transport planning, but their technical complexity requires an expert team, advanced software and computers and a very costly home-based survey, databases and infrastructure models. All these may be unaffordable for many municipal administrations and just a good excuse to keep on doing things the old way. The key is to find methods that suppose an innovation, whereas they do not require a great amount of resources. That is why in NODES, we propose tools that may be adaptable to each context and always be meaningful even if planners cannot complete the whole toolkit. Instead of an '*all-or-nothing'* methodology (in which '*all'* is usually '*too much*'), we propose tools made of 'bits', in which 'every bit counts', so each city could take as much as they would be able to.

4. A conceptual framework: transport and urban planning, dynamics, uses and integration.

In order to find new tools to better integrate land use planning and transport planning, focusing in the case of transport interchanges, there are many possible approaches. Most of them usually propose some coordination policies based on accepted principles, such as that population and employment must be highly concentrated in higher accessibility areas, such as the interchange stations surroundings. This principle has guided many models like Transport-Oriented Developments (TOD) in the US, Curitiba masterplan, or the ABC location policy in the Netherlands. However, NODES Project tries to analyze each interchange point as a unique case, based on the current land-use and transport dynamics, with an emphasis on differences in centrality and strategic role of each place. We do not determine a few types or classes of locations to define different recommendations. Instead, we try to understand the specific role of the node within the system, and consequently there is a special attention at integration properties.

In order to better analyze the land use-transport integration topic, classify and understand different indicators –both traditional and innovative–, we propose four subtopics, which are the result of crossing two dualisms (figure 1):

- First, *"urban and land planning"* versus *"mobility and transport planning"*. This common misconnection between two different professional practices is the main reason which triggers NODES Task 3.2.
- Second, *"content, use and functional dynamics"* versus *"spaces, network and infrastructure"*. Planning practice sometimes proposes an action on infrastructure and spaces. These spaces, stations, lines, roads,... integrate a network. Other times, planning practice regulates the use and allowed dynamics within those spaces and infrastructure. Even though, both actions usually come together when opening new infrastructure/spaces, planning may change regulations of use in the future.

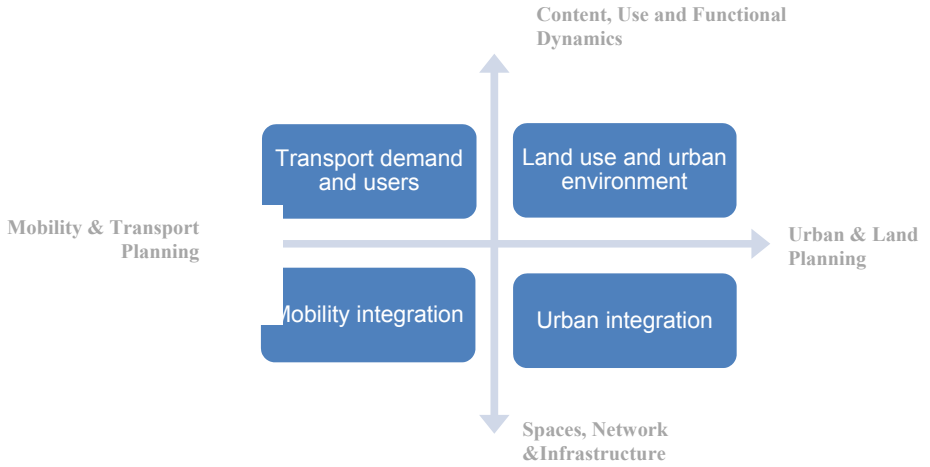

Figure 1: Conceptual framework.

Once crossed both dualisms in a matrix, four subtopics are identified: (1) Transport demand and users, (2) Mobility integration, (3) Urban integration, and (4) Land use and urban environment.

- Although all four subtopics are relevant, it is true that some subtopics may seem more significant than others depending on the scale of the approach. Next NODES subtask 3.2.2. will be more focused on the urban environment, whereas this section –at a city/regional scale (3.2.1)– pay more attention to mobility integration, which is considered a priority and 'reason-to-be' of the interchange on its own right.
- The first subtopic *"Transport demand and users"* can be considered more an objective or goal than an instrument for planning.
- Subtopic 2 *"Mobility integration"* represents the challenge that transport interchanges deal with. An interchange offers different types of mobility solutions in an integrated manner, not only through the various modes of public transport but also through complementary modes or mobility services (including pedestrians, bikes, park&ride, kiss&ride, car sharing, etc.), trying to adapt to users demand and needs and promoting a more sustainable transport. It is evident that the role of an interchange depends not only on the number of lines per mode, but also on what lines are those: do they articulate the whole system or simply extend the service without deeper impact for the rest of the network?

In order to describe how integrated transports are at each interchange, topological network properties are considered. These can describe the strategic role of each interchange within the complete system, in terms of hierarchy of accessibility, or centrality. We propose the use of three network variables: closeness centrality, straightness and betweenness centrality, based on Curtis' proposal (2011).

- Subtopic 3 *"Urban integration"* takes into account the hierarchy of the network of streets and public space. In particular, Space Syntax (Hillier and Hanson, 1984; Hillier, 2007) investigates relationships between spatial layout and a range of social, economic and environmental phenomena through a configurational analysis of the urban street network. Space Syntax has proved its capacity to explain diverse phenomena, in particular, the natural movement of pedestrians, all based on a hierarchy of more connected and more integrated urban spaces.

  According to this theory, land uses seek naturally their right place within the city in relation to natural movement, and not the opposite. Consequently, land uses (present and future) may be analyzed from the spatial layout. But, following the same logics, Space Syntax constitutes a package of important tools for urban planning and design, in order to "create the right places" to host specific land uses, therefore considered ahead during the planning stage. Two of their variables are taken as indicators for our methodology: global integration and local integration.

- Subtopic 4 *"Land use and urban environment"* includes a complete range of descriptors to characterize the urban environment of each interchange facility and understand potential trip generation and attractiveness of the area.

  Urban morpho-typology is also included to provide a fine detailed description of the urban morphology, not only by a typical index of total built floor surface ('built density') but also how this is distributed and thus perceived ('open space ratio') and the scale of roads and blocks ('road density' or 'average block size').

5. Tool for general diagnosis and identification of prior areas for intervention.

In the first place a tool is developed for a complete understanding and diagnosis of the public transport network, its integration, relationship with land uses and the strategic role of a point within the whole network. Moreover, this tool may enable to detect present needs and prior areas for intervention and/or investment. Authorities must therefore make balanced decisions in order to satisfy multiple interests and possibilities.

The tool is a chart that constitutes a framework to understand multiple relationships between the diverse subtopics, which are described by each subtopic indicators. Indicators may be calculated with both current and expected/planned data. This will depend on the purpose of the study: analysis of current situation or prospective strategic study.

Each relationship is calculated by a bi-variable linear correlation, the well-known statistical method that provides a value R describing the intensity of association between variables. R can vary from -1 to 1. A summary of results is generated by fulfilling R values of all indicators, grouped by subtopics. Cells must be shaded in different colours according to R-values to allow a quick identification of the most intense relationships and/or the most alarming lacks of coordination. The latter could be interpreted as strategic aspects to be improved or potentialities.

This chart, as a tool, allows authorities, planners and stakeholders to identify and measure relationships (strong/medium/weak/lack of), but this does not mean that a strong relationship is always to be desired: each relationship (or lack of it) must be independently considered through environmental, economical, civil rights, principles and consequences. Then, it must be determined if the analyzed situation is acceptable or, on the contrary, to be corrected.

Moreover, thanks to scatter plots representations that reflect the relationship of each pair of

indicators, individual cases can be identified and analyzed. 'Outliers' suppose exceptional cases that could be taken into account as prior cases for intervention in order to get them closer to desired standards.

	Subtopic 1: Transport demand.	Subtopic 2: Mobility integration.	Subtopic 3: Urban integration.	Subtopic 4: Land use & urban environm.
Subtopic 1	1.	12.	13.	14.
Subtopic 2		2.	23.	24.
Subtopic 3			3.	34.
Subtopic 4				4.

Figure 2: Scheme of tool for diagnosis.

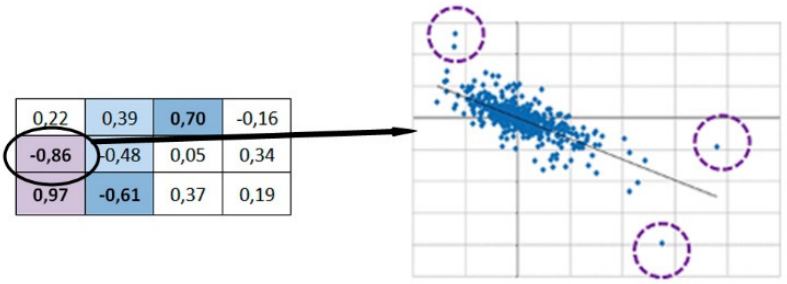

Figure 3 : Example of identification of prior areas for investment or intervention.

6. Tool to evaluate scenarios for a new interchange.

A simpler more reduced tool enables to inform and guide the project of a new interchange. Since tools are not designed to reach a unique optimal decision, which is not easy to define or not always existing/available, we propose a limited number of indicators to evaluate each scenario. The effort to reduce the number of indicators is considered crucial to facilitate the practical use of the tool.

Many of the indicators proposed for task 3.2. have a stronger relevance and impact at a more local, close-up level: the urban environment, so they will acquire a more important role for NODES tools in 3.2.2. However, at a city or regional level, there are many particular, contextual, 'non-systematizable' facts that usually lead to the final decision for the interchange location. Some of them might be: (i) Existing intermodal connections points that require improvements, extensions, or a completely new facility; (ii) already existing transport stations that will be expanded or re-designed to host new transport modes or lines; (iii) availability or access to public land of a certain required size; and (iv) regeneration policies or investment opportunities in strategic locations of the city.

These reasons may probably explain the location of most of the present-day interchanges in Europe. Consequently, all these situations should not be omitted but taken into account, since some of them suppose important opportunities or even *conditio sine qua non* for the interchange development. Nevertheless, a project such as NODES, which aims to provide an innovative tool no matter contextual individual facts, needs to push the question and go further than these

considerations. The above reasons will reduce the number of possible selectable locations to only a few sites in the metropolitan area. Then, for each site, one or more connections to the public transport systems and consequent mobility integration might be possible. These combinations eventually limit the new interchange development to a number of new intervention possibilities or 'scenarios'. Any difference in location, modes or connections involves a different scenario to be evaluated independently (see Figures 4 and 5).

Example of generation of scenarios		
Location	**Connections proposal**	**Scenarios**
Site **1**	Mode **M** (line **m1**) and mode **N** (line **n1**)	→ **Scenario A**
	Mode **M** (lines **m1** and **m2**)	→ **Scenario B**
Site **2**	Mode **M** (line **m2**) and mode **N** (lines **n2** and **n3**)	→ **Scenario C**
	Mode **M** (lines **m2** and **m3**) and mode **N** (line **n3**)	→ **Scenario D**
	Mode **M** (line **m2**), mode **N** (lines **n2** and **n3**) and mode **P** (line **p1**)	→ **Scenario E**
Site **3**	Mode **N** (lines **n1**, **n2** and **n3**) and mode **P** (line **p1**).	→ **Scenario F**

Figure 4: Example of generation of scenarios.

Where should a new interchange located? At a general city/regional level, several indicators are considered the 'keystone' to select the most suitable scenario in order to optimize the interchange performance (see figure 7).

The interchange performance can be evaluated by its real-measurable improvement of modal integration of the whole public transport network and its efficiency.

What are the qualities that make an interchange attractive and competitive? No doubt there is a lot of relevant factors concerning the design and travel experience, as well as the closest urban environment (as other NODES Work Packages will develop). However, at a city/regional level, it is the strategic position of the interchange and its connections (direct or not) what makes an interchange competitive. Understood as a key-node of the transport network, travel times are reduced and the whole travel experience seems easier and more comfortable.

The first objective is to enhance mobility integration, by reducing travel times and necessary transfers, in other words, to optimize closeness and straightness centrality measures.

- Closeness centrality of the interchange (Curtis, 2011) can be calculated as the average travel time to 'all other' transport nodes of the network. This is an indicator of objective accessibility and strategic position and, moreover, helps to identify and measure potentialities as an origin or destination.
- The impact of the interchange on closeness centrality of the other nodes must also be analyzed. A new interchange must have a positive impact on the whole network efficiency. By providing new connections between nodes, lines and transport modes, an interchange should have a direct impact on closeness centrality of the other nodes. In other words, the new development must provoke a general reduction of travel times.
- Straightness centrality of the interchange (or 'degree centrality', as described in Curtis, 2011) can be calculated as the average number of necessary transfers to reach 'all other' transport nodes of the network (figure 6). This is an indicator of topologically direct accessibility and

another aspect of strategic position. Thus, it helps to identify and measure potentialities as an origin or destination, as well.

Example of two real scenarios: Madrid Principe Pío 1985-2007		
Location	**Connections proposal**	**Scenarios**
Site **1: Príncipe Pio**	*Modes and itineraries:* **National railway** (various destinations), **Suburban bus** (tree lines), **Urderground metro** (line **R**) **Urban bus** (several lines)	→ **Scenario A**
Site **1: Príncipe Pio** (interchange development)	*Modes and itineraries:* **Commuters railway** (lines **C7** and **C10**), **Suburban bus** (**26** lines), **Long-distance bus** (various destinations), **Urderground metro** (lines**R**, **6** and**10**) **Urban bus** (several lines)	→ **Scenario B**

Figure 5 : Example of two real scenarios.

- The impact of the interchange on straightness centrality of the other nodes must also be analysed. A new interchange must have a positive impact on the whole network efficiency and mobility integration. By providing new connections between nodes, lines and transport modes, an interchange should have a direct impact on straightness centrality of the other nodes, causing a general reduction of necessary transfers.

Travel time and necessary transfers combined can describe all kinds of transport users between two extremes: the one that wants to reach their destination as soon as possible, no matter the necessary transfers and the other that does not care about time but about comfort and reducing the physical activity that transfers implies.

Another kind of objective that must be achieved concerns urban local integration. It has been proved as determinant for the success of an interchange to be properly integrated within its urban environment. Local integration correlates with people's ability of wayfinding in the interchange vicinity, which is crucial for the efficient pedestrian access of the interchange. Also, well locally-integrated stations attract a higher demand of soft transport modes, especially urban bus.

If the urban interchange is planned as one of the major transport interchanges in the city or town that aims to articulate metropolitan public transport, additional requirements are necessary:

- Urban global integration: also in terms of Space Syntax methodology, the interchange must be placed at a major location, not only to be 'central' or accessible from the whole city sprawl as it could be, but also to quickly be introduced in the inhabitants' cognitive map of the city.

The locations of these interchange nodes must strike a balance with the peripherally located stations, which are necessary due to the heavy congestion generated by large cities and central circulatory areas. An interesting fact of Space Syntax is that it identifies areas that may not be at the geographical center of a city – where availability of land tends to be lower – whereas they are globally-integrated and thus are equally optimal for urban dynamics (sometimes even better).

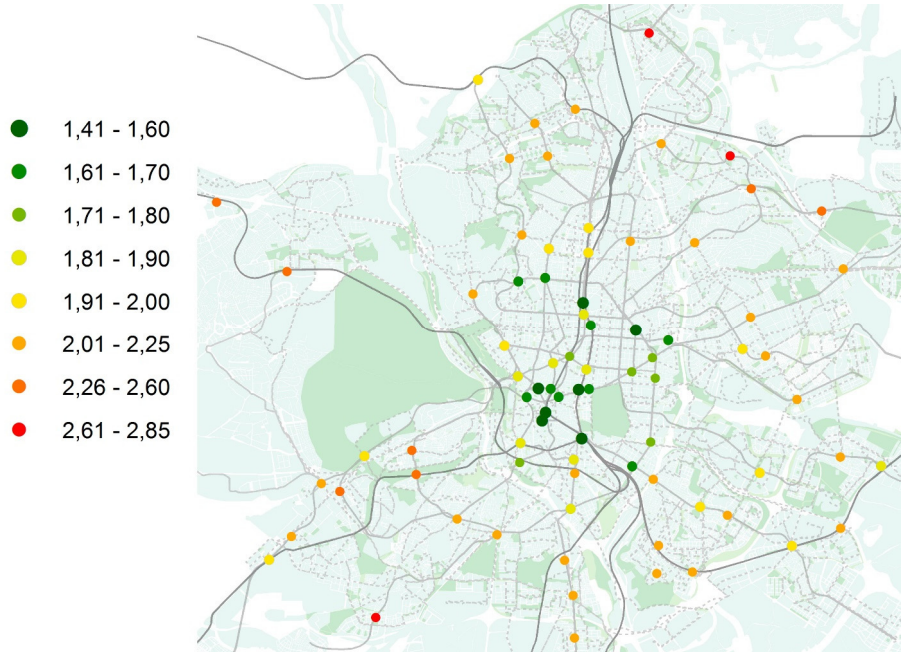

Figure 6: Straightness centrality in transport nodes in Madrid city.

- Also, the through-movement potential must be studied. This is measured by the "betweenness centrality measure (Curtis, 2011), that identifies the transport nodes that will be traversed the most by journeys between different pairs of nodes after all potential journey combinations are considered. It captures the geographical distribution of public transport flows between each pair of nodes across the network.

NODES	Interchange Location at a City-Regional Level (any case)					If Relevance	
	1a. Closeness centrality.	**1b.** Impact on Closeness values of other nodes in the network.	**2a.** Straightness centrality.	**2b.** Impact on Straigthness values of other nodes in the network.	**3.** Urban Local Integration	**5.** Urban Global Integration.	**5.** Betweenness centrality.
Scenario A							
Scenario B							
Scenario C							

Figure 7: Scheme chart to assist a new interchange planning.

This must be analyzed carefully. Betweenness centrality provides a prediction of the future potential demand as a sum of "to-movement" and "through-movement" and, consequently helps to inform the design process and control economical investment. Betweenness centrality distribution, analyzing all nodes, must be considered. It might be sensible to invest on the really necessary infrastructure, without leaking out of travellers already existing stations.

7. Conclusions.

The urban dimension is so complex and full of divergent interests that each particular intervention and case will involve dealing with different problems or priorities, thus difficult to assess in a single straight way. This requires an open adaptable methodology. Within NODES Task 3.2. "Integrated land use and infrastructure planning" and more specifically, at city/regional level (3.2.1.). we have tried to propose an open methodology, so that it could be adaptable to the context of each city and to the availability of technical and human resources, but also to different targets that transport authorities and stakeholders may have. NODES tools aim to strengthen and enrich the professional practice and the decision-making progress, not to provide an automatic response. That is the reason why there is no quantitative objects to reach.

We have proposed a conceptual framework to integrate transport- and urban studies, open to common planning practice and open to a multi-scale approach. This framework is a previous necessary task to break down the main topic 3.2.1 'Mobility analysis and urban planning at city/regional level' (so generic as a starting point) into four relevant subtopics: 1) Transport demand and users. 2) Mobility integration. 3) Urban integration. 4) Land use and urban environment. At the same time, the methodology is proposed to be perfectly consistent with the next part of task: 3.2.2. 'Urban planning and development at a close-up level' integrating both issues into a multi-scale approach where intermediary levels may also be considered.

The four subtopics enable a fresh yet solid starting point, in an objective, target-free, yet relevant way. They synthesize the main characteristics that describe a new interchange, its urban position and context, but also its relevance within the transport network. It has also been considered essential to focus the issue on the fields where transport- and urban planners have a wider scope for action. Each subtopic is developed by a collection of key indicators based on consolidated academic literature of a certain consensus and planning traditional practice data collection. In other words, based in usually available data and skills.

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