A Gellish model in Formal English
Example of a road network

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1 Introduction

This document describes as example an information model of a road network in order to elucidate the use of the Formal English language, a member of the Gellish family of formalized languages[1]. The example is taken from the civil technology application domain. With some imagination, this example can be converted into other application domains.
The accompanying CSV data file with a table in Gellish Expression format contains the example model of the road network and house as well as the definition of some used concepts, knowledge and constraints (requirements) as well as a translation of the concepts in the Dutch language. This document and the example, together with Gellish powered software[2] illustrate the capabilities of Gellish for data exchange and data integration. It also demonstrates the automated translation of a model that is expressed in one Gellish language variant to any other language. For example from Gellish English to Gellish Dutch and vice versa.
This document with an accompanying product model in Gellish Expression format is also available in Dutch.

Further information about the definition of the Gellish language, its taxonomic dictionary - ontology and the definition of the standard Gellish Expression format can be found on the Gellish website: http://www.gellish.net. That website includes a wiki that describes an outline of the Gellish Modeling Methodology and a User Manual for the Gellish Communicator software. It also contains a typical section of the language definition. The Gellish language definition is described in the book 'Semantic Information Modeling in Formalized languages' and the methodology is described in the book: 'Semantic Information Modeling Methodology'. The full language definition, including the taxonomic dictionary – ontology can be licesed via the website.

Note 1: Concepts such as those that are defined in this document, as well as the knowledge that is expressed by relations between those concepts, may be added to the language definition on an ad-hoc basis, or may be included in the Gellish Taxonomic Dictionary. Once such concepts and knowledge are added to the Gellish dictionary, they can be re-used by other models and then the don't need to be redefined each time.

Note 2: Relevant choices on the use of Gellish are clarified in text that is enclosed by a text box.

2 Basic assumptions (context)

The modeled example includes a description in Gellish Formal English of a part of a road in a road network with a few roundabouts and a house along one of the roads.

The description is such that, for example, it is possible to perform calculations about streams of traffic on the basis of the modeled traffic intensity.

Figure 1: Scheme of Road net_1 presents (a part of) the road network:

The road segment (N5) connects roundabout 1 (R1) with roundabout 2 (R2). Roundabout 2 is also connected to two other roads (N51 and N52).

Road N5 consists of two *tracks* each with two *lanes* and a *middle shoulder*. Road N51 and N52 both are roads with *single lane tracks*.

The following aspects are relevant for the execution of calculations:

- The intensity of the traffic stream on the roads

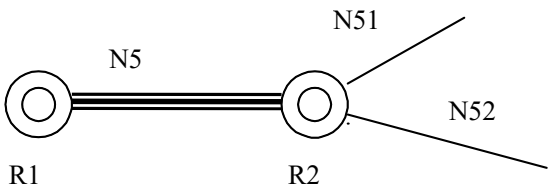


Figure 1: Scheme of Road net_1

[1] The Formal English is a further development of ISO 10303-221 and ISO 15926-2 and 4 and several other standards. The Gellish dictionary is partially included in ISO 15926-4.

[2] The predicate 'Gellish powered' with the associated logo is allowed to be used only by applications that are certified by the Gellish Forum.

- The capacity of the roads
- The distribution of the flow of entry and exit traffic on the roundabouts.

The concepts that are required for the classification of the roads and their components, as well as for the classification of the aspects that are relevant for making the calculations have to be available in the Gellish dictionary.

The roads should be described as part of a particular road network; each road shall be uniquely identified.

The roads are described by the road manager, which does not need to be the owner of the roads.

Approach

1 Addition of concepts that are not yet included in the dictionary to ensure that the nomenclature and taxonomy are available in the language definition.:
   a. Concepts about a road.
   b. Concepts about a road network (for the calculations).
   c. Concepts required for the calculations.
2 Description of the roads.
3 Description of streams of traffic through the network for making calculations.

3 Nomenclature, dictionary and taxonomy

For the description of the road network or part of such a network, it is necessary to include concepts in the taxonomic dictionary for the description of:

- The physical components of the road network; the roads, entries, exits, roundabouts, etc.
- The structure of the road network
- The streams of traffic in the road network

Note: For a complete road network there are also other components required, such as tunnel, viaduct, road crossing, rail road crossing, traffic sign, car park, etc., all with their various subtypes.

In Gellish any concept is added to the Gellish Taxonomic Dictionary by:

- The specification of a unique identifier and a name and its possible aliases, such as synonyms , abbreviations and translations. This forms the Nomenclature of the formal language(s).
- The specification of a specialization relation, being a subtype-supertype relation, with the direct supertype of the concept. This forms the Taxonomy.
- The specification of a textual definition. This forms the Dictionary.

In addition to such a definition of concepts it is possible to express knowledge about the concepts. This is done through relations of particular kinds between the concepts. For example, explicitly modeled definitions, specifying the values of characteristics of concepts that are by definition the case and specifying which concepts are by definition part of a larger assembly. Such definitional knowledge is included in the Gellish Taxonomic Dictionary – Ontology. Other examples are, specifications of possible parts of assemblies, possible aspects of objects and possible roles that things can play towards other things, etc. Such expressed possibilities for kinds of things belong to Gellish Knowledge bases.

3.1 Road network

The concept ‘road’ has a number of subtypes. For example:

- Subtypes by specialization according to its number of tracks. The subtypes are defined by modeling their subtype-supertype relations as follows:

- single track road is a kind of road
- double track road is a kind of road
- double track road with four lanes is a kind of double track road

- Subtypes by specialization according to construction and suitability regarding speed and capacity:
  - city road is a kind of road
  - provincial road is a kind of road
  - state road is a kind of road

Note 1: These terms are common terms (in The Netherlands) for specific kinds of roads. The terms are derived from the kind of party that is usually owner of such a road. However, ownership of a road is independent of the kind of road as is illustrated below.

Note 2: The above specialization relations are accompanied by textual addendums that specify in which respect a subtype concept is more constrained than its supertype concept and in which respect it is distinguished from the other subtypes of the same supertype concept. Those texts are not shown here.

A typical difficulty in developing a taxonomic dictionary and definitions of concepts is the distinction between kinds of things and kinds of applications of things, being kinds of usage or kinds of roles of things. This is caused by the use of terms for denoting real subtypes and/or use of the same term for denoting kinds of roles of objects. This is illustrated by the following example.
In addition to the kinds of roads it is possible that a road can play a number of roles. For example a road can play the following roles in an ownership relation:

- *road of a municipality* *can be a role of a* *road*
- *road of a province* *can be a role of a* *road*
- *road of a state* *can be a role of a* *road*
- *road of a municipality* is a kind of *property (of an owner)*
- *road of a province* is a kind of *property*
- *road of a state* is a kind of *property*
- *property* is a kind of *role*

Note: For clarity we have chosen descriptive terms for the kinds of roles instead of their usual terms. The usual terminology for the above mentioned roles (for example 'provincial road') are homonyms for kinds of roads. In Gellish the subtypes and the kinds of roles are different concepts with different unique identifiers (UID's). For clarity of the example, they are here replaced by less common terms. For example the role 'state road' is replaced by its synonym 'road of a state'. However, it is possible in Gellish to use identical terms for different concepts, How such homonyms are distinguished is beyongd the scope of this document.
Such role concepts are not always necessary for describing relations, because the relations are usually unambiguously defined through relations such as relations of the type 'is owner of'. For that reason the above kinds of roles are not included in the attached Gellish product model.

Knowledge about possible components of a road includes for example that a road can have the following parts:

- track can be a part of a road
- lane can be a part of a track
- hard shoulder can be a part of a track
- edging can be a part of a track
- verge can be a part of a track
- end of a road can be a part of a road

- road entry is a kind of track
- road exit is a kind of track

The last two lines imply (by inheritance) that an entry and an exit can also be a part of a road.

The concept roundabout has for example the following subtypes:

- Subtypes by specialization according to number of lanes:
  - two lane roundabout is a kind of roundabout
  - three lane roundabout is a kind of roundabout
  - four lane roundabout is a kind of roundabout

A roundabout for example can have the following components (sub-parts):

- lane can be a part of a roundabout
- centre can be a part of a roundabout
- shoulder can be a part of a roundabout
- road exit can be a part of a roundabout

4 Modeling remarks and questions

4.1 Property (ownership)

The property of a road is specified by the usage of a relation of type ‘is owned by’. This is a relation between a physical object and a party that is the owner.

Remark

In principle two other ways of modeling would be possible:

- The owner could be included as characteristic of the physical object.
- The owner could be used as a discriminating aspect of the kind physical object. This way of modeling would lead to a subtype of the kind of physical object for each owner or kind of owner. Potentially there are a lot of them.

Both ways of modeling are incorrect, because an owner is a person or organization and not a (subtype of) characteristic. And a persons or organization is also not an aspect of a road.
This is also the reason why there is no specialization defined for road and roundabout on the basis of ownership.

4.2 End of a road or track

A road or track has two terminals. Each of them has to be treated as a road end (piece), whereas the concept ‘road end’ does not define a direction. The concepts ‘start end’ and ‘termination end’ are roles of a road end, because a route may start at one end and another route may start at the end where the first route terminates.

In addition to that, it is possible that a track can have connections for entries and exits.

Large roads can have hectometer posts and numbered exits, which sequence numbers indicate which end of those roads is the start end and which one is the termination end.

Remark

The relation type that indicates that a route is ‘from… to …’ also indicates which end has the role of start end in a route and which end has the role of termination end in that route.
In other words, the first role of the relation indicates the start end and the second role indicates the termination end.

End-1 as well as end-2 (start end, as well as termination end) can be located in space by giving them coordinates in a coordinate system. The same holds for the ends of tracks.

4.3 A road and its parts

The part of a road between two roundabouts can be a road segment.

For example, assume that the N57 is a road from Amsterdam to Groningen. Then that whole is classified as a road. In that case a particular part of that road between two roundabouts near Groningen is classified as a road segment. The roundabouts may be part of other roads as well.

> **Remark**
>
> The term 'part' indicates a role of something relative to something else that has the role of whole. It is (in Gellish) possible to specify that a road is part of a (bigger) road. Whether that is the case in practice depends on the conventions for defining roads that are applied in practice.

In this example we distinguish a road and a road segment, being part of the road.

5 The road network

A road network is a network that can have as components:

- things with a role of node
- things with a role of vertex that connects two nodes.

Roundabouts, crossings, viaducts, etc. are things that can have a role as nodes in a road network. Roads are things with a role of connector between those nodes.

So, it is possible to describe a road network at a high level as follows:

roundabout	can have a role as a	road connect node
roundabout	can be a part of a	road network
road segment	can be a part of a	road network
roundabout	can be connected to a	road segment

and

road network	is a kind of	network
road connect point	is a kind of	role
road connection	is a kind of	role

The road network can be described at a lower level as follows:

entry and exit	can be a part of a	roundabout
road end	can be a part of a	road segment
entry and exit	can be connected to a	road end

The road network can be described at a detailed level as follows:

roundabout	can be connected via a	road connection assembly
road segment	can be connected via a	road connection assembly
entry and exit	can be a part of a	road connection assembly
road end	can be a part of a	road connection assembly

A road connection assembly is an assembly of parts that are involved in the connection. For example, a road end, sign posts, detection loops, a public square, etc.

Remark

This is similar as connections of other kinds. For example, a connection in an electric network, or in a piping system in which parts are involved such as a piping end, flanges, packing, bolts and nuts or a weld, etc.

6 Traffic streams and their characteristics in a road network

When aspects of components of a road network are described it is possible for example to perform calculations about traffic intensity. The traffic engineering theory is based on three concepts: traffic intensity, traffic density and velocity.

Therefore, the following concepts are required for a calculation about a traffic intensity:

traffic stream	is a kind of	stream

A traffic stream is a (physical) stream of vehicles. A traffic stream can have as characteristic a traffic intensity.

traffic intensity	is a kind of	frequency

The characteristic traffic intensity (q) is a frequency with which vehicles pass a particular location. Usually it is a characteristic of a traffic stream. A traffic intensity is quantified on a scale ‘number per time period’. Possible scales are 1/h, 1/d, etc.

Note : The unit of measure can also be indicated by a role of a unit of measure. For example: ‘number of vehicles per hour’.

traffic density	is a kind of	linear item density

The traffic density (k) is a number of vehicles per distance. The unit of measure is for example: 1/km, number of vehicles per km or per other unit of road length.

track capacity	is a kind of	traffic intensity

A track capacity is a traffic intensity for which a track is designed. So, usually a track capacity is an aspect of a track.

Note: It is difficult to define a road capacity in an unambiguous way, because the track capacities of the road can be different.

velocity	is a kind of	vector property

A velocity (v) is a vector property of which the magnitude is determined by the distance that is passed within a period of time and that has a direction. In this context the velocity is usually an aspect of a traffic stream. The unit of measure is for example: kilometer per hour (km/h).

traffic discharge	is a kind of	ratio

A traffic discharge is a ratio between a traffic intensity at an exit relative to the traffic intensity of the track just before the exit. So, it is a ratio between aspects of two different traffic streams. Usually it is a characteristic that is experienced by a track and by an exit.

traffic supply	is a kind of	ratio

A traffic supply is a ratio between a traffic intensity at an entry relative to the traffic intensity on the track after the entry.

For road traffic the following correlation holds: $q = k * v$.

It is possible to include characteristics of the above mentioned objects as well as characteristics (of other objects) that ‘are experienced’ by those objects in a model with information about a road.

For example:

road	can have as aspect a	road capacity
road	can experience as aspect a	traffic intensity
traffic stream	can have as aspect a	traffic intensity

Usage of a road by traffic streams means that a large number of road transport processes take place. Each of them is a road transport between two nodes (including nodes at entries and exits) where a traffic stream moves from a start end to a termination end of a track segment.

traffic transport	is a kind of	transport process
traffic transport	can use as facility a	track segment
traffic transport	can have as subject a	traffic stream

The latest two relations could be summarized via a ‘short-cut relation’ in which the transport process remains implicit (a ‘short-cut relation’ is a relation that implicitly includes more than one relation):

traffic stream	can move via a	track segment

7 Requirements

Various kinds of requirements can be expressed for a road and its components. For example the following general requirement for a “bottom of a road” (Rijkswaterstaat Road-63 requirement):

> “The remaining settling difference after 10 years of begin of usage shall be less than maximally 0.05 m on 25 m in length direction.”

This requirement can be expressed In Gellish as follows:

bottom of a road	shall be compliant with	The remaining settling difference after 10 years of begin of usage shall be less than maximally 0.05 m per 25 m in length direction.

This Road-63 requirement may or may not be expressed in an explicit way. An explicit expression of the same requirement for example results in the following partial requirements:

left hand object name	relation type name	right hand object name	UoM
bottom of a road	shall have as aspect a	remaining settling difference per 25 meter in length direction after 10 years of usage	
remaining settling difference per 25 meter in length direction after 10 years of usage	shall have on scale a value less than	0.002	m/m

It is possible that in different contexts different requirements are applicable for the same aspect. For example this can be the case for different principals. This can be specified as follows:

context	left hand object name	relation type name	right hand object name	UoM
	bottom of a road	shall have as aspect a	remaining settling difference per 25 meter in length direction after 10 years of usage	
context-1	remaining settling difference per 25 meter in length direction after 10 years of usage	shall have on scale a value less than	0.002	m/m
context-2	remaining settling difference per 25 meter in length direction after 10 years of usage	shall have on scale a value less than	0.003	m/m

It is also possible that for a particular kind of road a particular requirement is applicable, whereas for another kind of road another requirement is applicable. In such a case, the requirement is applicable for an aspect, provided that the aspect is possessed by a particular kind of road. In other words, the

requirement is applicable for an aspect in a particular role.
This can be specified as follows:

left hand object name	relation type name	role (possessed aspect)	right hand object name (aspect)	UoM
bottom of a road type A	shall have as aspect a	difference for road type A	remaining settling difference per 25 meter in length direction after 10 years of usage	
bottom of a road type B	shall have as aspect a	difference for road type B	remaining settling difference per 25 meter in length direction after 10 years of usage	
difference for road type A	shall have on scale a value less than		0.002	m/m
difference for road type B	shall have on scale a value less than		0.003	m/m

This specification means that when a part of a road is classified as a ‘bottom of a road’, then this requirement by definition applies to that part of such a road, as is illustrated below.

8 Part of the road network

In the description of a particular part of the road network (Road net_1) the roads and roundabouts have a unique name, such as N5, N51 and N52 and R1 and R2, as illustrated in Figure 2.

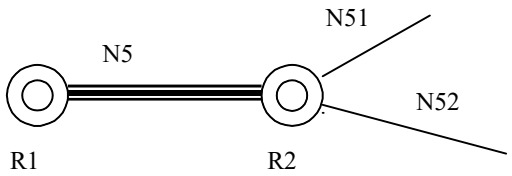


Figure 2, Scheme of Road net_1

Together with the description of the components of the network, we also describe the network as a whole. Such a description of the network can be used, for example, to calculate traffic flow rates in the network.

The relations between the specific components are relations between individual things. Such relations have another meaning than the relations between kinds of things. Therefore, the names of the relation types that are used in the description of the specific network below are different from the names of the relation types that are used to describe the knowledge about roads in general, as used above.

For example, for the description of the composition of a specific network (or a part thereof) and for the specification of entries and exits we use the relation type ‘is a part of’ (as opposed to the relation type ‘can be a part of a’ above).

The specification of the nature of the parts provides a relation with the concepts in the taxonomy. This is specified using the relation type ‘is classified as a’.

The connections between the parts is specified using the relation type ‘is connected to’.

Description of Road net_1:

Road net_1 is classified as a road network

N5	is a part of	Road net_1
N51	is a part of	Road net_1
N52	is a part of	Road net_1
R1	is a part of	Road net_1
R2	is a part of	Road net_1
road network	is a kind of	network
N5	is classified as a	road
N51	is classified as a	road with three separated carriageways
N51	has a role as a	provincial road
N52	is classified as a	dual carriageway
R1	is classified as a	roundabout
R2	is classified as a	roundabout
E5_1	is a part of	N5
E5_2	is a part of	N5
E51_1	is a part of	N51
E51_2	is a part of	N51
E52_1	is a part of	N52
E52_2	is a part of	N52
U1_1	is a part of	R1
U2_1	is a part of	R2
U2_2	is a part of	R2
U2_3	is a part of	R2
E5_1	is classified as a	road end
E5_2	is classified as a	road end
E51_1	is classified as a	road end
E51_2	is classified as a	road end
E52_1	is classified as a	road end
E52_2	is classified as a	road end
U1_1	is classified as a	road exit
U2_1	is classified as a	road exit
U2_2	is classified as a	road exit
U2_3	is classified as a	road exit
U1_1	is connected to	E5_1
U2_1	is connected to	E5_2
U2_2	is connected to	E51_1
U2_3	is connected to	E52_1
N5	is owned by	The Dutch state
N51	is owned by	Province Groningen

N52	is owned by	Municipality Groningen
Substructure-N51	is classified as a	substructure of a road
Substructure-N51	is a part of	N51

It is not necessary to separately describe the network that is used to make the calculations about the traffic flow rates, because that network is already defined through the specification of Road net_1.

Question:

Is it required to specify explicitly the the roads and roundabouts that are part of Road net_1 are also part of the whole Dutch road network?

Answer:

No, because parts of parts are automatically also parts of the whole.

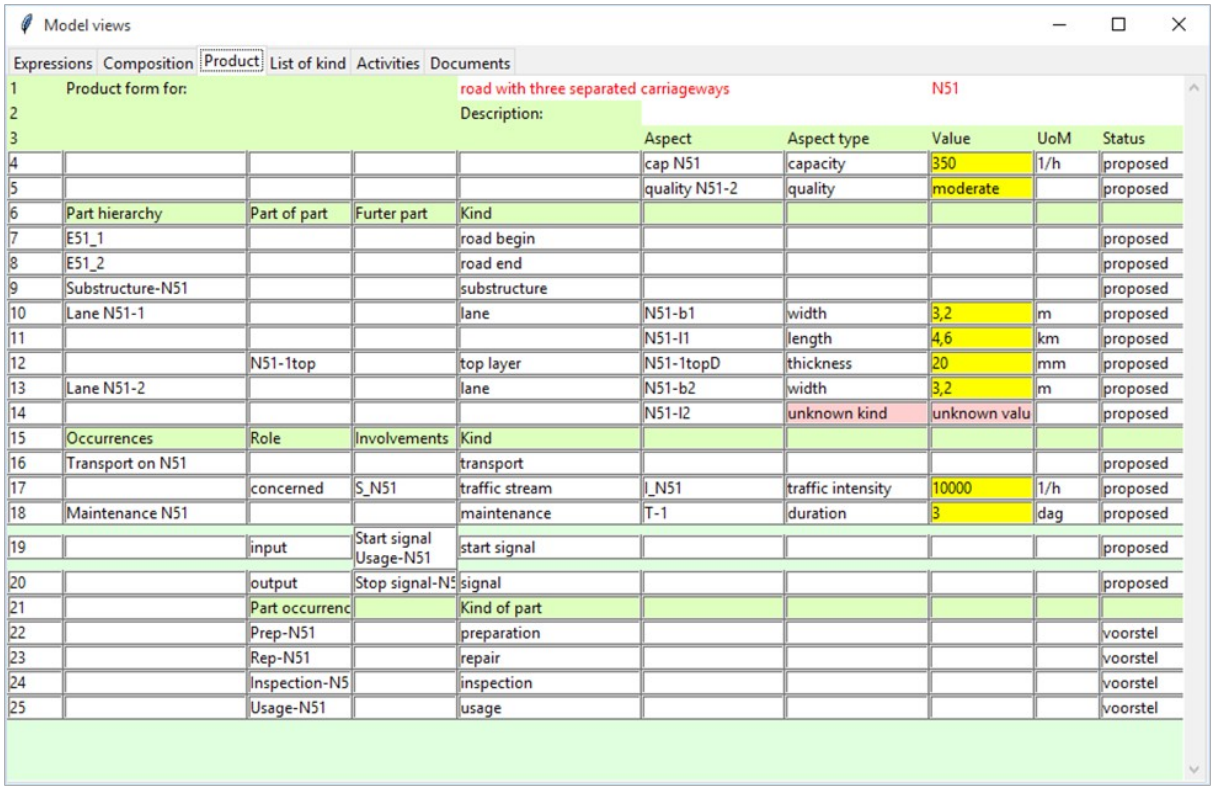
Note: It is possible that parts of the road network, such as lamp standards, guardrails, shoulders, etc., are not relevant for making calculations of traffic flow rates. *Irrespective of that they are parts of the whole, whereas they are ignored during a query on the relevant parts and aspects.*

Description of the traffic flows in the network:

S_N5	is classified as a	traffic stream	
S_N51	is classified as a	traffic stream	
S_N52	is classified as a	traffic stream	
S_N5	has as aspect	I_N5	
S_N51	has as aspect	I_N51	
S_N52	has as aspect	I_N52	
I_N5	is classified as a	traffic intensity	
I_N5	is quantified as	15000	1/h
I_N51	is classified as a	traffic intensity	
I_N51	is quantified as	10000	1/h
I_N52	is classified as a	traffic intensity	
I_N52	is quantified as	5000	1/h
U1_1	has as aspect	A1_1	
U2_1	has as aspect	A2_2	
U2_2	has as aspect	A2_2	
U2_3	has as aspect	A2_3	
A1_1	is classified as a	outgoing traffic	
A1_1	is quantified as	80	%
A2_1	is classified as a	outgoing traffic	
A2_1	is quantified as	60	%
A2_2	is classified as a	outgoing traffic	
A2_2	is quantified as	20	%
A2_3	is classified as a	outgoing traffic	
A2_3	is quantified as	20	%

9 Model views

The Gellish expressions in this document are part of the electronic data file with the 'product model' that is an appendix to this document. Files such as that file can be produced by Gellish enabled software and can be exchanged with other Gellish enabled software systems. An example of such a system is the Gellish Communicator application. It can read Gellish files, such as the appended CSV file, and enables searching and displaying any objects and their components in various views. The following figure presents one of the views of road N51, with some modified data and including also additional maintenance activities.



Model views

Expressions | Composition | Product | List of kind | Activities | Documents

1	Product form for:			road with three separated carriageways			N51		
2				Description:					
3					Aspect	Aspect type	Value	UoM	Status
4					cap N51	capacity	350	1/h	proposed
5					quality N51-2	quality	moderate		proposed
6	Part hierarchy	Part of part	Furter part	Kind					
7	E51_1			road begin					proposed
8	E51_2			road end					proposed
9	Substructure-N51			substructure					proposed
10	Lane N51-1			lane	N51-b1	width	3,2	m	proposed
11					N51-l1	length	4,6	km	proposed
12		N51-1top		top layer	N51-1topD	thickness	20	mm	proposed
13	Lane N51-2			lane	N51-b2	width	3,2	m	proposed
14					N51-l2	unknown kind	unknown valu		proposed
15	Occurrences	Role	Involvements	Kind					
16	Transport on N51			transport					proposed
17		concerned	S_N51	traffic stream	I_N51	traffic intensity	10000	1/h	proposed
18	Maintenance N51			maintenance	T-1	duration	3	dag	proposed
19		input	Start signal Usage-N51	start signal					proposed
20		output	Stop signal-N5	signal					proposed
21		Part occurrenc		Kind of part					
22		Prep-N51		preparation					voorstel
23		Rep-N51		repair					voorstel
24		Inspection-N5		inspection					voorstel
25		Usage-N51		usage					voorstel

Figure 3: Product model view of road N51

One of the features of the Communicator software system is that it can extract the expressions that form a view, such as the above N51 view, and export them in a new CSV or JSON file for exchange with other Gellish enabled systems.

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