Transport and infrastructure knowledge decomposition with reference models

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Abstract

This paper describes seven reference models that can be used to structure relevant topics in the process of designing and developing a program for an Executive Masters of Transport & Infrastructure. It shows the necessity to study the field of transport systems from an inter-disciplinary viewpoint. It seems evident that structuring relevant topics and emphasizing the relationships between these topics, will make it easier to develop a knowledge structure to mimic important transport systems issues. Before one can develop a curriculum, for a program that addresses transport systems in their full complexity, one should first build a framework to (re)-structure transport and infrastructure related knowledge. Several reference models can be used as a backbone to build such a framework. Reference models discussed and analyses in this paper are: (1) Confetti Reference Model, (2) Mono-Disciplinary Reference Model, (3) Causal Relationship Reference Model, (4) Layered System Reference Model, (5) Systems Engineering, Policy Analysis & Management Reference Model, (6) Life Cycle Engineering & Management Reference Model, and (7) Restricted A La Carte Reference Model. Based on qualitative analyses these reference models are assessed. The Systems Engineering, Policy Analysis & Management Reference Model flavoured with the Layered System Reference Model seems to be the most suitable reference model to use as the backbone for the design of the curriculum for a new Executive Master of Transport & Infrastructure at the Delft University of Technology.

1 Introduction

Transportation and mobility are the lifelines of each society. An adequate functioning transport system provides considerable opportunities in the process
of adding value to social and financial wealth. Transport systems will become out-dated if they cannot keep-up with the constant-changing needs of our society. Continuous improvement of our transport systems to fulfil the changing mobility demands of individuals and the society as a whole is of great importance.

All transport systems are embedded in the larger society and consist out of specific sub-systems. Numerous public and private organisations and institutions are involved in the engineering and management of transport systems. It provides great opportunities for individuals employed by these organisations and institutions, regardless of their background and prior education, to speak the same language and to gain adequate insight in the characteristics of problems that are related to the engineering and management of transport systems.

2 Executive Master of Transport and Infrastructure

The Executive Master of Transport and Infrastructure (MTI) aims to provide for individuals that work in or want to work in the field of transportation insight to understand transport systems and their characteristics. It seeks to educate these individuals the necessary theoretical and practical methods and tools to engineer and manage transport systems in an integrative way. It aims to provide these individuals a generic language, on both engineering and management to approach and solve complex problems in a collaborative manner.

The field of transportation is very broad, so some decisions regarding the main focus should be made. As a result of an earlier market inquiry it was decided to take a passenger focus rather than a freight focus. Following a passenger focus immediately implies a focus on road and rail transport systems and enough attention to multi-modal passenger terminals (nodes in the transport network).

3 Knowledge decomposition by means of reference models

Within the program structure, all relevant topics should offer the student enough knowledge and insight to understand and solve complex problems in the field. Before one can select topics for a Masters program, good understanding of transportation, the transportation system and related issues is necessary.

Several reference models can be selected to decompose knowledge in the field of transportation. All of these reference models can also be used as the main structure for the development of the program for the Executive Master of Transport & Infrastructure. The goal for discussing these reference models is to select the most important transport related topics for the course and to select a useful structure or reference model for the total Masters program and the modules that will be part of this program. The use of reference models is widely accepted and some very useful examples can be found in the literature [1]. The following reference models will be briefly discussed:

- Confetti Reference Model
- Mono-Disciplinary Reference Model
• Causal Relationship Reference Model
• Layered System Reference Model
• Systems Engineering, Policy Analysis & Management Reference Model
• Life Cycle Engineering & Management Reference Model
• Restricted A La Carte Reference Model

The author agrees that many more reference models can be found, but more models were not assessed within this study.

4 Confetti Reference Model

The first way to look at the field of transportation is to sum-up a series of relevant topics and to bring them under the same umbrella (figure 1). Often a rough decomposition can be made, differentiating between for example managerial topics, engineering topics and case studies (integrative topics). Another possibility may be to differentiate between private & public issues.

![Figure 1: Confetti Reference Model.](image)

The Confetti Reference Model can be easily engineered and maintained because the elements of the model are loosely coupled. Disadvantage is maintaining the central thought or focus within the model. Each topic focuses mainly on the internal aspects of the topic, without any integral consistency. Often a series of special cases or themes or a central case or theme can be used to relate or explain the elements of the model in respect to all chosen elements.

5 Mono-Disciplinary Reference Model

A very common way to look at the field of Transport & Infrastructure is based on the Mono-Disciplinary Reference Model (see figure 2). This model is a representation of the most widespread way science looks at problems. Each scientist is preaching its own discipline; showing methods and tools one “should” apply to tackle problems. Depending on the discipline, scientists are open for other interpretations, often found within gamma-disciplines.
Mono-disciplinary has the disadvantage that it decomposes the field of Transport & Infrastructure into disciplines, and by doing so; omit the fact that problems are often of an inter-disciplinary nature. The advantage of this model is the multi-focus students will get on the same type of problem, a sequential integrative approach. The dominance of a specific perspective can be shown by analysis of historical cases. Under the guidance of an experienced and pragmatic project and/or process managers of transport & infrastructure projects students can practice the relevance of particular perspectives and see the value of a more parallel integrative approach.

6 Causal Relationship Reference Model

The Causal Relationship Reference Model (figure 3) focuses on the relationship between topics. Van Wee and Dijst use a causal relationship model to explain the inter-relativeness of topics that are important from a viewpoint of transport policy [2]. Programs based on this model will probably discuss a series of important topics in the field of transportation and will focus on bridging the gap between other important topics. Examples can be discussed to explain the topic and/or relationship and the impact these relations have on decisions.

One of the advantages of the Causal Relationship Reference Model is the connectivity between topics addressed in the field. It will give students in the field of transportation a good notion of the connectivity and interdependency of topics during policy, planning and decision-making. One of the big disadvantages of the Causal Relationship Reference Model is the lack of hierarchy and category of relationships. One can always add another topic or define another sub-topics in two or more topics. This model concentrates on the demands and services and the problems related to these aspects, but do lack a specific focus on the (physical) transport system as such.
Figure 3: Causal Relationship Reference Model.

Figure 4: Layered System Reference Model.
7 Layered System Reference Model

The Layered System Reference Model (figure 4) consists out of several layers and interfaces between these layers. This model is widely used within the Delft University of Technology. Every underlying layer supplies services directly to the layer above and indirectly to the higher layers. Each layer above makes demands upon services supplied by the underlying layer(s). The Transportation Services and Transportation Means and the in-between interface Asset Management both form the heart of the layered system model. The interface Traffic Coordination connects the Infrastructure layer and the interface Transportation Marketing connects the actual demand of passenger’s flows and freight flows.

The value of the Layered System Reference Model is that topics may be discussed in respect to the layer or interface one wants to address, and shows at the same time the relevance of the topic in respect to the other layers. Another advantage is the possibility to concentrate on specific aspects of the solutions within each layer. A disadvantage of the model is that it gives a very strict or artificial interpretation of the transport system itself. In real transportation projects, decision makers and organisation involved are not reasoning according to these layers. The reference model shows this deficiency by some of the added surrounding topics.

8 Systems Engineering & Policy Analysis Management Reference Model

The Systems Engineering & Policy Analysis Management Reference Model (figure 5) focuses on decomposing the field of Transport & Infrastructure in four main directions. Some directions cover hard engineering issues and some directions more soft management issues. Nevertheless hard and soft methods are applicable in all directions. The first direction focuses on the physical structure of the transport systems itself, decomposable into the lower layers of the layered based systems, with layers like transport infrastructure, road, railway, waterway, airway, and the transport means and supporting facilities. The second direction addresses project management as a systems engineering approach, with relevant decision support and problem solving environments. The third direction covers transport services that together with the physical transport infrastructure can fulfil the needs of passenger / driver (the customer). The fourth direction focuses on organisation and management issues necessary to support the need to fulfilment processes during the life cycle of transport systems.

One of the main advantages of the Systems Engineering & Policy Analysis Management Reference Model is the fact that issues addressed in each direction can be easily coupled to the other directions by means of examples. This means that often the same examples can be used in lecturing the relevant aspects in each direction. If cases are organised around increasing complexity levels, it holds the opportunity to provide a true integrative model for a Transport & Infrastructure Program. On of the disadvantages is the need for each lecturer to really focus on
their own discipline, but to use at the same time within his or her presentations and educational material the same (type) of case, as examples. Another disadvantage or maybe better characteristic is formed by the fact that some special integrative modules are necessary to test the ability to use an integrative perspective in the field of transport & infrastructure. Of course this can also be a requisite of the program.

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<thead>
<tr>
<th>Transport Services</th>
<th>Transport Systems</th>
<th>Transport Economy</th>
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<tr>
<td>Traffic aspects</td>
<td>General T-Service Aspects</td>
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<td>Demand Aspects</td>
<td>General T-Systems Aspects</td>
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<td>Place Promotion</td>
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</tbody>
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Figure 5: Systems Engineering & Policy Analysis & Management Reference Model.

9 Life Cycle Engineering & Management Reference Model

The Life Cycle Engineering & Management Reference Model (figure 6) focuses on decomposing the field of transport & infrastructure in life cycle phases relevant to transport systems. A life cycle approach is based on a model of sequential life cycle phases as an extension of the phases one can find within Systems Engineering practices [3]. Within each phase of the life cycle of a transport system several typical aspects are addressed. This can be done very differently. Normally a typical transport system engineering approach can be chosen as a way to view the aspects within each life cycle phase. A dedicated project procedure, like those required for the construction of infrastructure and transport systems funded by the government (MIT-procedure) or a typical systems engineering approach for the development for traffic information systems or transport means, may be followed. It is possible and recommended to create focus, to integrate one or more already discussed reference models within each phase of the Life Cycle Engineering & Management Reference Model. The Systems Engineering & Policy Analysis & Management Reference Model is inherent related to the life cycle and fits because of this best.
One of the main advantages of the Life Cycle Engineering & Management Reference Model is the fact that it gives a good interpretation of the whole life cycle and its relevant aspects of transport systems. It gives the opportunity to analyse historical projects and to anticipate on planned projects. Another advantage is the fact that a rich case database of historical and current projects exists. This means that relevant organisations that where part of historical projects can be consulted or brought into the program as lecturers. This opens the possibility to have expert and critics (lecturers) together analysing, working and learning from these projects. One of the disadvantages is the need for each lecturer to interpret and make analyses of the historical and current projects that are discussed during the course. Interactions between representatives of organizations that were stake-holder in the chosen cases looks ideal, though only a select group of lecturers are willing or able to lead or be part of these sessions. Another disadvantages might be that the reserved time for teaching theories, methods and tools is limited by the time consumed for discussing cases. To correct this the duration of the total course can be prolonged.

10 Restricted A La Carte Reference Model

The Restricted A La Carte Reference Model tries to adjust a course participant prior knowledge, work experience and interests to given course structure. The Restricted A La Carte Reference Model consists out of some required basic modules in the beginning of the course to learn the goals of the course and to get acquainted with the other participants. Based on the personal preference a set of existing courses is selected. The students may either follow regular courses at the Delft University of Technology or other institutes, but more often make arrangements with the program director or his/her supervisor to do an oral exam or write an assignment on provided course material. To make this manageable and to prepare the possibility of the participant to follow courses a list of possible electives is prescribed. To integrate knowledge integrative modules, like cases for small groups. At last an individual thesis is written.

One of the main advantages of the Restricted A La Carte Reference Model is the fact that it completely fulfils personal needs. It also opens the opportunity to interact with other participant during case studies. One of the disadvantages is the choice between the modules that are given in the classroom and those
modules that are part of individual programs. Another disadvantage is the fact that forming a common language and a focus on the integrative approach may not be fulfilled to its full right with this course structure.

<table>
<thead>
<tr>
<th>Course Reference Model</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Confetti Reference Model</td>
<td>It can be easily engineered and maintained because the elements of the model are loosely coupled.</td>
<td>It is difficult to maintain the central thought or focus. No integral consistency.</td>
</tr>
<tr>
<td>Mono-Disciplinary Reference Model</td>
<td>Students get a multi-focus on the same type of problem.</td>
<td>Decomposing the field of transport &amp; infrastructure into disciplines omits the fact that problems are inter-disciplinary.</td>
</tr>
<tr>
<td>Causal Relationship Reference Model</td>
<td>Connectivity &amp; inter-dependency between topics is addressed. It shows the complexity of the transport system as a whole.</td>
<td>One can arbitrary add other topics. It lacks a focus on the (physical) transport system as such.</td>
</tr>
<tr>
<td>Layered System Reference Model</td>
<td>Topics are discussed in respect to layers and their relevance to topics within other layers at the same time. It is possible to focus on specific aspects within each layer.</td>
<td>It has a very strict or artificial interpretation of the transport system itself.</td>
</tr>
<tr>
<td>Systems Engineering &amp; Policy Analysis Management Reference Model</td>
<td>Issues addresses in each direction can be easily coupled to other directions by means of examples to understand the intergrality. Cases may be organised around increasing complexity levels.</td>
<td>There is a need for each lecturer to really focus on their discipline and use within his or her presentation the same (type) of case.</td>
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<td>Life Cycle Engineering &amp; Management Reference Model</td>
<td>It gives a good interpretation of the whole life cycle and its relevant aspects of transport systems. It gives the opportunity to analyse both historical and to be planned projects. It opens the possibility to have expert and critics together analysing, working and learning from these projects.</td>
<td>Lecturers need to interpret and make analyses of the historical and current projects that are discussed during the course. The transmission time for theories, methods and tools is limited by the time consumed for discussing cases.</td>
</tr>
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<td>Restricted A La Carte Reference Model</td>
<td>It completely fulfils personal needs. It also opens the opportunity to interact with other participant during case studies.</td>
<td>Continuous attention to the available of courses is necessary. Forming a common language and focus on the integrative approach may not be fulfilled.</td>
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### 11 Conclusions and Preferred Course Reference Model

Based on this comparison one can conclude:

- From a potential student point of view, the preferred Course Reference Model is the Restricted A La Carte Reference Model, followed by the Life Cycle Engineering & Management Reference Model are preferable.
From an organisational point of view the course the Confetti Reference Model, followed by the Mono-Disciplinary Reference Model are preferable.

From an educational point of view, the Systems Engineering & Policy Analysis Management Reference Model, followed by Life Cycle Engineering & Management Reference Model.

From a potential student point of view, the Confetti Reference Model followed by the Mono-Disciplinary Reference Model, are not preferable.

From a course organisational point of view the Life Cycle Engineering & Management Reference Model followed by the Causal Relationship Reference Model are not preferable.

From an educational point of view, the Confetti Reference Model followed, by the Mono-Disciplinary Reference Model are not preferable.

The Layered System Reference Model and the Systems Engineering & Policy Analysis Management Reference Model are the models most preferable to use as the backbone for the development of the curriculum of the Executive Master of Transport & Infrastructure. The Layered System Reference Model is expected to pose problems in respect to selecting adequate lecturers, so the System Engineering & Policy Analysis Model is selected as the backbone for the development of the Executive Masters in Transport & Infrastructure. For cases the other reference models can be combined with the chosen reference model.

References

