

On the right tracks? Continuous broadband Internet on trains.

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Abstract—Passenger internet on-board of trains is being deployed worldwide. The cost is however too large to be sustained by a single service thus rollouts are often delayed or cancelled. Running new applications over the same infrastructure to increase revenue is therefore essential for future sustainable deployments yet current techno-economic models suffer from several limitations. Among others, they do not consider the interactions between actors. Using value network analysis, we investigate whether the interactions between actors can be categorized. This paper reports on the identified Value Network Configurations (VNCs) and discusses the impact on the profitability of a rollout. Six commercial rollouts were analysed and could be classified belonging to 3 VNCs: (1) the conventional model, (2) the consortium model and (3) the train operating company model. The conventional model cannot guarantee continuous connection. Both the consortium- and the train operating company model can yet the consortium agreement in the consortium model is a hurdle for profitability. As a consequence, the VNC should be taken into account for evaluating future rollouts. Still, other economic and technical effects affect future rollouts and will therefore remain the focus of further work.

I. PROBLEM DEFINITION

Equipping a train with a broadband connection means that passengers can benefit from an on-board wi-fi (wireless fidelity) hotspot service that works similar to the fixed wi-fi hotspots found in hotels, train stations or airports. One of the first drivers was the “always connected” idea for mobile users, but in the mean time this idea has evolved beyond providing pure internet access for passengers, to a better way of managing the trains in all aspects. This includes comfort services like passenger info screens, or cost saving applications such as remote maintenance and software upgrades, or security related applications like CCTV systems [1].

The provisioning of wireless data services in a moving train is a technologically demanding challenge. Several technologies - including satellite, mobile and dedicated wireless - can meet the requirements yet in different ways. The choice of the best technology is dependent of many parameters such as the train type, the environment through which the train travels or the choice of services. The technical solutions and the choice of the right technology is well documented in literature [1], [2], [3], [4]. Current commercial deployments apply multiple technologies jointly within the same network [3]. Despite

the technological complexness the major challenges are not due to technology. Less understood and under documented in literature is the topic of selecting the applications that can increase revenue or decrease costs in order to realize a positive business case for all actors involved.

The correct selective introduction of new services that run over the same communication network will determine the future success of on-board internet services [5]. However in many cases train operating companies (TOC) are not interested in operating an “Internet on-board service” for passengers as their main business is transportation of people or cargo [1]. So often there are external business parties involved such as the train constructing company (TCC), mobile network operator (NOP), the system integrator (INT), the service provider (SP) and the content provider (CP). Our hypothesis is that business actors and their interactions influence the ease of introduction, the adoption rate and the business potential of the selected service mix. Therefore service operators should take these into account as accurately as possible in strategic decisions.

The goal of this paper is to propose a classification that is easy to apply and allows to evaluate the influence of the value network type on the selected service mix, revenue- or savings potential and business model for each service. In Section II of this paper the internet services on-board of trains are discussed and classified in four main categories: (1) pure passenger internet, (2) passenger comfort services, (3) security related applications and (4) cost saving applications. In Section III, we discuss a selection of reference commercial rollouts in Europe and their mode of operation. Section IV proposes a typology of value network actors and their interactions. In section V, the suggested value networks are illustrated by applying them to the reference commercial rollouts from Section III. In Section VI we discuss the proposed classification of value networks. Finally, Section VII summarizes the paper. In Section VIII we discuss future work.

II. CLASSIFICATION OF INTERNET SERVICES ON-BOARD OF TRAINS

The availability of high-speed broadband connections on vehicles opens up possibilities for new categories of services. Each kind of service has different network requirements.

Services such as sending an e-mail, checking social media updates or reading online news papers can cope with a non-continuous network connection, low bandwidth and high delays. Other services such as real time video applications require continuous network connection, high bandwidth and low delays. Services can be categorized in four distinct categories as proposed by [1]:

- Pure passenger internet (cat. 1) is the driver to install broadband, continuous internet access. The available bandwidth is often limited to discourage the transfer of large files and live streaming of video.
- Passenger comfort services (cat. 2). These include pure internet access, information services like info screens and entertainment applications such as multimedia information including sport and entertainment headlines, latest news and advertisements. These enhance the passenger experience while spending time on the train by making better use of otherwise “dead time”. Internet access can drive new revenues and increase ridership through a modal switch by passengers switching from road- and air travel towards rail. For example, a 2004 study in the United Kingdom found that 72% of business travelers were more likely to use trains than cars or airplanes if wi-fi access was available on trains [6].
- Safety and security related applications (cat. 3). These meet the need for improved security on trains which is often driven by government requirements. CCTV (Closed Circuit TV) systems are deployed more and more often on public transport to improve passenger and staff security and to decrease crimes such as vandalism. With an on-board broadband connection it is possible to access the video footage and live camera feeds remotely while the vehicle is in transit enabling the train operating company to significantly reduce response time to incidents. It is also possible to improve train safety by providing advanced warning of hazards ahead. This AHWS (Advance Hazard Warning System) can be used to provide train staff with video coverage of the next road crossing or next station.
- Cost saving applications (cat. 4). These help to reduce operational costs and improve train utilization. With a broadband connection and a GPS (Global Positioning System) receiver it is possible to track a vehicle in (near) real time. GPS coordinates are sent over the internet making a vehicle’s current- and past position visible on a map via a web browser. Modern train fleets contain systems for monitoring, recording and controlling on-board systems. This information can be transferred to where it is needed and can be used to manage the daily running of the trains more effectively, to increase train availability and support more effective maintenance regimes. It’s also possible to prepare trains remotely and reduce fuel costs by monitoring energy usage and driver training.

project	launch date	service mix	model
NMBS/SNCF (Belgium)	2005 2007	cat. 4 cat. 4	conventional
Thalys (Belgium, France, Germany, Netherlands)	2005 2012	cat.1,2 cat. 4	consortium
Virgin Trains (United Kingdom)	2009	cat.1	consortium/train operating company model
Nederlandse Spoorwegen (Netherlands)	2005 2011	cat. 1 cat. 4	train operating company
National Express (United Kingdom)	2011	cat. 1,2,3,4	train operating company
RZD (Russia)	2011	cat.1,2,4	consortium/train operating company model

Fig. 1. Most early implementations limit services to pure passenger internet and passenger comfort services, more recently cost saving and security applications are added to the mix.

The range of applications is very diverse and new applications are developed continuously.

III. DESCRIPTION OF SERVICE MIX FOR IMPLEMENTATION EFFORTS IN EUROPE

Both [1] and [3] list a number of implementation efforts in Europe. We refer to [3] for a discussion of the chosen technical solution and to [1] for a list of projects and their mode of operation. We describe the service mix for a selection of reference implementation efforts in Europe. In table 1 the projects and their launch date is summarized, each with their service mix.

NMBS/SNCF, the Belgian government-owned railway operator, does not offer continuous broadband internet services on-board of its trains. Passengers can use internet but they need a device, e.g. a smartphone with a data connection, that can connect directly to the cellular infrastructure, no other internet enabled services are offered to passengers. On the contrary, since 2005 train crew uses a mobile device to look up information about train schedules and to sell tickets on-board of trains. This mobile device requires a General Packet Radio Service (GPRS) connection to be operational. In 2007, GPS receivers were installed on every train. The GPS location of the train is tracked and sent via sms to the wayside.

Thalys, a European TOC operating high-speed trains between Paris, Brussels, Amsterdam and Cologne, started in 2005 with an offering of on-board broadband internet. By 2008 Thalys claimed that all of its trains provided broadband internet access. Other passenger comfort services offered on Thalys trains are an online portal website on which passengers can see the location of the train and rich multimedia content. In the future, the on-board wireless network will also be used for ticketless travelling applications on WiFi enabled PDA’s of train managers.

Nederlandse Spoorwegen (NS), a Dutch government owned TOC, started tests with on-board broadband internet in 2005. In 2011 the service has been rolled out in the 100th train. NS claims that by 2013 all of its trains will be equipped with wi-fi hotspots. NS provides free, on-board broadband wi-fi and

real time travel information presented via screens to all of its passengers. In 2011, Nederlandse Spoorwegen has started to expand its use of the available IP network by using services that can decrease operational costs through improved staff communication and remote operational applications.

Since 2009 all passengers on the West Coast Main Line (WCML) route, which is operated by the UK based transit operator Virgin Trains, can use wireless Internet via wi-fi hotspots.

In 2011, National Express launched broadband internet access on its 30 new Bombardier Class 379 trains on the Stansted Express route between Stansted Airport and London. Icomera supplied the system to provide internet access for passengers, staff- and on-board systems including CCTV, passenger information and Bombardier's train management system.

In 2011, RZD, the Russian government owned railway operator, launched continuous on-board broadband internet access for passengers and passenger information screens in resto coaches. The same communication network is used for on-board system monitoring and GPS positioning.

Most early implementations limit services to pure passenger internet and passenger comfort services, more recently cost saving and security applications are added to the mix.

IV. TYPOLOGY OF VALUE NETWORK CONFIGURATIONS BEYOND THE ON-BOARD INTERNET SERVICES

The general framework for studying value networks is defined in [7]. In our view a value network is a general perspective on how value is created by offering a certain product or service. We define a value configuration as the specific implementation of a value network for a product or service, i.e. continuous on-board broadband internet services. According to [8] an internet service on-board of trains does not appeal to a mass market but will attract a rather limited but heavily interested niche. Demand from business passengers has moved the provisioning of wireless broadband to a priority item on the agendas of transit operators around the world. According to [1], in many cases train operating companies (TOC) are not interested in operating an "Internet on-board service" for passengers as their main business is transportation of people or cargo. So often there are other actors involved which is visualized in figure 2. The most important actors are:

- TOC: a train operating company is the entity that operates the trains for passenger and/or cargo transport.
- TCC: a train constructing company manufactures trains which are sold to TOCs.
- NOP: a (mobile) network operator is a company that provides trains (possibly together with normal users) with wireless access to the wayside.
- INT: an integrator is a company that brings together component subsystems and ensures that those subsystems function together.
- SP: the service provider is the gateway between the end customer, the integrator and data center provider. The SP

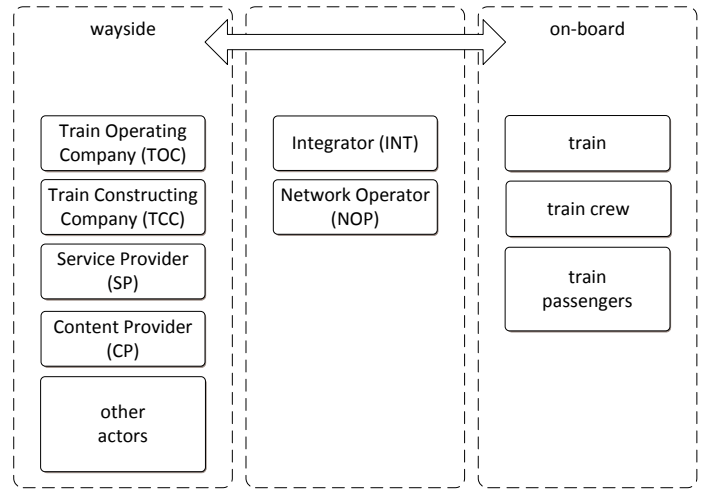


Fig. 2. From the onboard device, generating the data, until the wayside device that will process this data, different actors come into play as the data will subsequently pass their networks until it has arrived at its endpoint.

can be responsible for the portal when offering internet services or for selling time for advertising.

- CP: a content provider is an organization that creates informational, commercial, educational or entertainment content that is accessible on the train.
- the train is presented as a dummy actor as data will be sent from and to the train for monitoring, by machine-to-machine communication.
- the train crew are the driver, conductor and other personnel such as safety guards, bar keepers, etc.
- train passengers

In the next subsections we propose three categories of value network configurations, that are used to deliver the services described in section II. We also visualize these VNCs based on Figure 2. The actors using the services are always the same: train, train crew and train passengers. These are at the right side. The actors that deploy and operate a communication network are found in the middle of Figure 2. The actors that are using the communication to offer a service can be found at the left side. The interactions between these actors are illustrated by bidirectional arcs. The most important actors for each model are highlighted in gray. Actors that do not have a specific role are omitted.

A. The Conventional Model: No Dedicated Communication Network

The conventional model reflects the situation as is, in which no investments are done in a dedicated train network. It is the only model that cannot guarantee continuous broadband connectivity. Figure 3a highlights the relevant actors for the delivery of the communication network and the interactions with other actors. TOCs that have not introduced continuous on-board broadband passenger internet often consider the initial investment too high or wait until a next generation of technology is available.

B. The Consortium Model: An Outsourced Dedicated Communication Network

When the TOC is not interested in operating a continuous broadband on-board communication network other actors can still operate the service. In this context, the consortium model is defined as a value network configuration in which the offering of the actual transport of passengers or cargo and the offering of internet services on-board of trains are unbundled. These actors can be system integrators (INT), telecom network operators (NOP), mobile or satellite, or a combination [1]. This is illustrated in figure 3b. Other actors such as a content provider (CP) can also be part of the consortium. In the consortium model, typically a separate venture is set up between multiple actors to develop and deliver continuous on-board broadband internet services. Costs and revenues are distributed inbetween. The main motivation for setting up a consortium is to make use of the complementary skills, knowledge and infrastructure of the other actors. In this model the involved actors bear the investments. They deploy a dedicated network to provide continuous broadband internet access on-board of trains. Costs and revenues from the provided services are allocated as stipulated in a managed service contract.

C. The Train Operating Company Model: An Insourced Dedicated Communication Network

The train operating company model is defined as a value network configuration in which the offering of the transport of passengers or cargo and the offering of internet services on-board of trains are bundled by the TOC. The train operating company is responsible for the selection of the right service mix and business model for each service. In most cases the TOC does not have the technical knowledge to implement and operate the service. This is outsourced but the service is offered by the TOC. On the one hand, when a dedicated communication network has to be installed on existing rolling stock a system integrator will implement and operate the communication network. This is illustrated in figure 3c. On the other hand, when a dedicated network has to be installed on newly purchased rolling stock, most TCCs will offer to do the installation of the required hardware during construction. This is illustrated in figure 3d. The integration of the hardware in the designs of the train can provide significant cost reductions that lower total capital expenditures. Like most TOCs the TCCs also focus on their core competency, building trains, as such they lack the expertise to deploy these services and subcontract the installation of hardware and operations of the network to a system integrator. In this model the TOC has control over the choice of the service mix and pricing strategy. For certain services, e.g. passenger information, the train operating company can work together with an external party, e.g. a content provider. The TOC bears all costs but receives also all revenues.

V. CLASSIFICATION OF COMMERCIAL ROLLOUTS BY VALUE NETWORK CONFIGURATION

The proposed typology of value network configurations in section IV is discussed in more detail by applying them to the commercial rollouts from section III.

NMBS/SNCF is an example of a TOC which, like many other TOCs, does not invest in a dedicated network. They do not perceive the added value large enough to justify the investment in a dedicated network and users interested in internet on-board of trains have to make use of the existing cellular network.

In 2007 Nokia Siemens Networks, a system integrator (INT), 21Net, a European operator specialized in providing broadband internet access to trains based on bi-directional satellite connectivity (NOP), and Telenet, a Belgian supplier of broadband cable services (SP), set up a consortium to offer continuous on-board broadband internet services on Thalys trains. It is the consortium that offers these services to the end customers and the end customers who pays a fee to the consortium for use of services. A first example is the enhancement of Thalys's Comfort 1 value offering with free internet access for passengers. As Thalys is not the owner of the consortium, Thalys has to pay a fee to the consortium for each sold Comfort 1 ticket. For Comfort 2 only access to the landing site is free. Rates are €6.50 for a 60 minute connection (elapsed time) or €13.00 for unlimited access during a ride. These fees are revenues for the consortium. Whenever Thalys wants to use the dedicated network for an application, e.g. a ticketless traveling application, it needs to use the solution provided by the consortium. Risk for the TOCs is very limited. The TOC does not receive any direct revenue although it may benefit from indirect benefits such as increased ridership. A comparable consortium has been set up for the RZD case.

Nederlandse Spoorwegen (TOC) and National Express (TOC) apply the train operating company model. Nederlandse Spoorwegen awarded a contract to Nomad Digital (INT) to rollout and operate a dedicated network on all of its trains. National Express launched broadband internet access on its 30 new Bombardier Class 379 trains on the Stansted Express route between Stansted Airport and London. Bombardier Transportation (TCC) does not have its own system to ensure an always on broadband connectivity and deploys Icomera's (INT) on-board Internet solution to provide high availability broadband internet access.

Not all commercial rollouts can be classified according to the proposed typology of value network configurations. Due to the rail environment it can be necessary to combine elements from the archetypal value network configurations. The UK franchise system for the rail environment makes long term investments challenging. To overcome this Virgin Trains (TOC) set up a partnership with Nomad Digital (INT) and T-Mobile (NOP) for a broadband service on their Class 390 Pendolino Trains and Class 220 & 221 Voyager trains on the West Coast Main Line. In this collaborative approach each does pay a share of the investments in capital expenditures

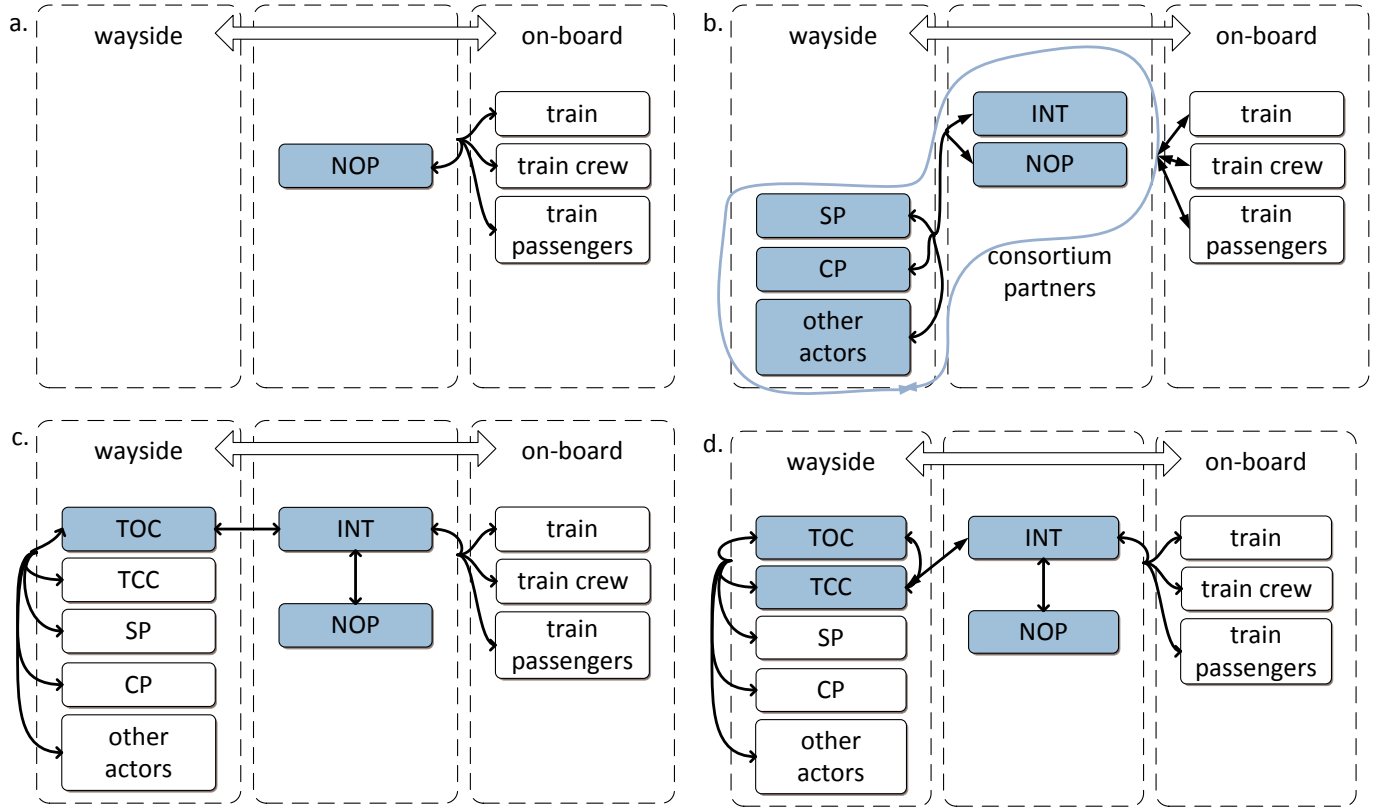


Fig. 3. a. The conventional model. No dedicated network is installed as such on-board actors can only make use of the network of the mobile network operator and wayside actors cannot offer services. b. The consortium model. A dedicated network is installed and operated by the consortium and the consortium decides who can make use of the network. The consortium partners will offer services to the users. c. The train operating company model for old trains. A dedicated network is installed on the existing trains of the TOC by a system integrator. The TOC can decide who can make use of the network. Other actors have to negotiate with the TCC to offer services over this network. d. The train operating company model for new trains. A dedicated network is installed on newly ordered trains of the TOC by the TCC. The rest of the model is the same as the model for the installation of a network on existing trains

and operational expenditures turning it into a mixture of the consortium model and the train operating company model.

VI. RELATIONSHIP BETWEEN VALUE NETWORK CONFIGURATIONS AND THE BUSINESS POTENTIAL OF A SERVICE

Continuous broadband internet access on-board of trains has been and remains to be the main trigger to invest in a dedicated network that can provide continuous on-board broadband internet. When such a communication network is available it can easily be leveraged by offering more applications over the same infrastructure. The choice of value network configuration does influence two factors: the possible applications that can be introduced and the business potential of the service.

The possible applications that can run over the communication network and their quality of service depend on the available bandwidth. An application that requires real-time video streaming, e.g. CCTV or an AHWS, requires a relative high bandwidth and a continuous connection. A decent quality of service cannot be guaranteed when no such network is available which is the situation with the conventional model. The same is true for both the consortium model and the train operating company model. However in many cases they will

develop a dedicated network that can support a broad range of services. In case of a dedicated network rollout, the limits of available bandwidth are less stringent and a guaranteed high quality of service for a CCTV application is possible.

The business potential is equally dependent on the quality of service but is also affected by other, less obvious reasons related to the chosen value network configuration. A use case example is the optimization of signal quality of voice calls on trains. In areas where cellular network service availability is poor or non-existent an on-board cellular picocell or femtocell can be the solution to improve or provide the cellular signal. All voice traffic is then backhauled over the communication network. Offering this service requires an agreement with the license owner of the used frequencies. These spectrum licenses are typically owned by network operators. The conventional model can certainly not offer this service as there is no wayside network available next to the available cellular infrastructure. The consortium model can have a dedicated network but will, in many cases, limit the business potential for this service. Most consortiums are built around a combination of a network operator and a system integrator. These parties operate the network and decide which applications run over the network.

A network operator is interested in realizing the best service for his customers as such the benefits of an on-board picocell or femtocell will only be available to passengers who are customer of this network operator limiting the total business potential of such a service. This is not the case for the train operating company model. A train operator will be looking for a maximum return and will open the on-board picocells or femtocells to all passengers.

Each of the three value network configurations has advantages and disadvantages for the service provider.

value network configurations	advantages	disadvantages
conventional model	- no investment needed in a dedicated network - can wait for future improvements in the network of the NOP	- limited to applications that don't require continuous broadband internet connectivity - no SLA
consortium model	- continuous broadband internet connectivity possible	- applications limited to those not in conflict with consortium partners interests
train operating company model	- continuous broadband internet connectivity possible - least conflicts possible	- large investment needed by TOC

VII. CONCLUSION

The ease of introduction and the success of a new service is related to the chosen value network configuration. The conventional model, in which no dedicated communication network is constructed, has a limited potential for introducing new services that require high bandwidth and low delays as continuous broadband connectivity cannot be guaranteed. In the consortium model, the actors will develop and deploy new services over a communication network and these actors will decide which external actors are allowed to use the available infrastructure and at which cost. The train operating company model is in contrary to the consortium model a model in which one actor can decide on which services will be allowed to run on top of the communication network.

However, given the large set of parameters that influence the decision of deploying a new service, a case specific analysis is necessary to evaluate the revenue- or cost saving potential of a service. This case specific evaluation does need to take into account three factors: (1) the guaranteed service level of the communication network and the cost to reach this service level (2) the value network configuration and (3) the demand for and potential benefits of the service.

VIII. FUTURE WORK

In future research we will develop an analysis tool that is able to evaluate the revenue side and cost side of services from the viewpoint of all relevant actors. With this tool business case scenarios will be compared to evaluate their economic viability. This future work has as purpose the further quantification of the business case for internet services on-board of trains.

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