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Review of underground logistic systems in the Netherlands: an ex-post evaluation of barriers, enablers and spin-offs

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Abstract

Now, 10 years after the first plans, we analyse in this paper what has happened with Underground Logistic Systems (ULS). The major question in this paper is: Which barriers and enablers led to the failure of ULS and what ULS spin-offs can be found nowadays? Several factors can be classified as barriers or enablers. The main conclusions that can be drawn are that the opportunities for try-out were too limited; political support could have been gained on higher levels; the costs were too high, the catchment area was too limited; ULS in itself is a very promising system, but there was no one clear goal. In particular, the lack of a thorough and positive business model in combination with a lack of sufficient freight volumes almost immediately guaranteed the failure of the initiative. The spin-offs seem to have taken place in different directions: ranging from rather soft impacts (e.g. scientific knowledge) to more hard developments (adopting and developing transport and tunnelling technologies), and, although difficult to quantify, they are of great value.

Keywords: Innovation management; Underground freight transport.

1. Introduction

In the 1990s, a research project was carried out in the Netherlands that focussed on underground freight transport for Schiphol airport. The title of the project was 'Ondergronds Logistiek Systeem' (Underground Logistic System or ULS). Several aspects of the innovative concept were researched in detail, and it was planned to have a system operational by 2005. Now, approximately 10 years after the first plans, it is

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interesting to see and analyse what has happened with the ULS. At first sight, it can be seen that the initiative is no longer alive. With the help of frameworks used to forecast potential success of innovations, post-innovation failure can also be analysed. Several publications (Wiegmans, 2005; van der Straten et al., 2007; Wiegmans et al., 2007) have dealt with the potential success of innovations in transport. Failure of innovations is not often researched, which is logical as people prefer to focus on success. However, analysing failure might bring insight into future success. And although not successfully implemented, ULS might have had considerable spin-off effects to other projects and/or transport sectors. The focus here is on the success and failure aspects of ULS. The problem analysed in this paper is as follows: *Which barriers and enablers led to the failure of ULS and what ULS spin-offs can be found nowadays?* First, the paper will discuss the characteristics of ULS. Secondly, a theoretical framework will be presented that consists of three elements: product characteristics; user requirements; and the innovation system, which all determine the success potential of transport innovations. Thirdly, ULS will be post-evaluated and reasons for failure will be identified. Furthermore, ULS spin-offs will be identified and analysed. The paper ends with some conclusions.

2. Underground logistic systems in the Netherlands

Underground freight transport deals with automated transport of general cargo by vehicles moving through an underground tunnel network. Because fundamental changes in the organisation of sending and receiving actors are necessary, underground freight transport in the Netherlands is also called underground logistic systems (ULS).

The history of ULS

In the 1970s, ideas were developed in the Netherlands for high-speed transport systems underground. In 1987, the International Systems Development and Support (ISDS) foundation developed the Integral Transport System (ITS) concept, a transport system that consists of a long-distance (more than 200 kilometres) underground high speed network (for passengers and freight), combined with local short-distance collection and distribution networks (only for freight). Between 1987 and 1993, several projects, financed by the national transport department, studied this concept in more detail.

In 1994, the Dutch Governmental Programme for Sustainable Development (DTO) organised several round-table discussions with experts and concerned stakeholders on sustainable technologies for transport in the future (Grontmij, 1994). Within the framework of this research programme, a definition study (Haccoû et al., 1996) was carried out to determine the feasibility and sustainability of underground transport in more detail, and to define the field of application. The study concluded that in the field of urban freight transport, no alternative sustainable transport modes were available except underground freight transport (compared with rail and waterborne alternatives that are available for long-distance transport). This study demonstrated that in urban areas underground freight transport was potentially a sustainable and competitive application. The next step, within the framework of the DTO, was to design a logistic

concept for underground freight transport within urban areas, and to define an implementation strategy. The work was carried out in 1996 and 1997 in the project 'tube transport of freight within urban areas' (Brouwer et al., 1997). The resulting concept was based on small tube-networks as a new, sustainable, logistic concept for commodity transport within urban areas.

Meanwhile, in 1995, private companies started two other underground freight projects. The Unit Transport by Pipe (UTP) project was based on a medium-distance (approximately 100 kilometres) underground connection for mini-containers between the seaports of Rotterdam and Antwerp (Raadgevend Ingenieursbureau Lievense et al., 1995). Another project, the ULS-project, dealt with the feasibility of an underground transport network for air cargo and flowers which would connect Schiphol Airport to the flower auction in Aalsmeer and a new rail-terminal in Hoofddorp. The ULS would make a seamless connection between air, rail and road possible. The feasibility scan, completed in 1996, concluded that the ULS could make an important contribution to the improvement of the accessibility of the Schiphol area, and could reduce the pressure on the environment. A second study, completed in 1997, focussed more on defining the direction of the project. This study produced some further financial and technical transparency and confirmed the findings of the feasibility scan. The (conceptual) design of the system was started in 1997 and continued through 1998 and 1999. A test site was realized in 1999 in Delft (the Netherlands) to test prototypes of the various automated vehicles and handling systems and to develop and test the control system (Pielage, 2005; Pielage and Rijsenbrij, 2005). These studies attracted the attention of a number of Dutch politicians, including members of the Dutch parliament. The Interdepartementale Projectorganisatie Ondergronds Transport (IPOT, Interdepartmental Project-team on Underground Transport), a government task force for the study of underground transport, was formed. In phase 1, the IPOT task force started by making an exploratory study of the feasibility of underground freight transport. Phase 2 concentrated on feasibility studies of local applications of underground freight transport systems, such as for industrial purposes in the area of Schiphol, Geleen and Arnhem/Nijmegen, and for the distribution of consumer goods in the urban areas of Twente, Utrecht, Leiden and Tilburg. Phase 3 concentrated on developing an overall nationwide concept for the Netherlands (IPOT 1998, 1999, 2000). In 2001, the Minister of Transport published a memorandum in which the development of underground freight transport was described as promising and that further development was necessary before it could be implemented as a measure to reduce or avoid congestion on the road infrastructure. The tests and development of the control system needed for ULS were carried out at the Connekt Test Site (formerly known as the ULS Test Site) at the Delft University of Technology. At that time, the ULS Schiphol project and Tilburg were still in progress, although it was considered that parts of these systems would not be built underground but on the surface as an automated system, using dedicated lanes.

ULS applications

Underground freight transport can have an important function as an alternative for road transport, for instance in the combined development of intermodal freight transport by rail or inland navigation and in urban freight transport.

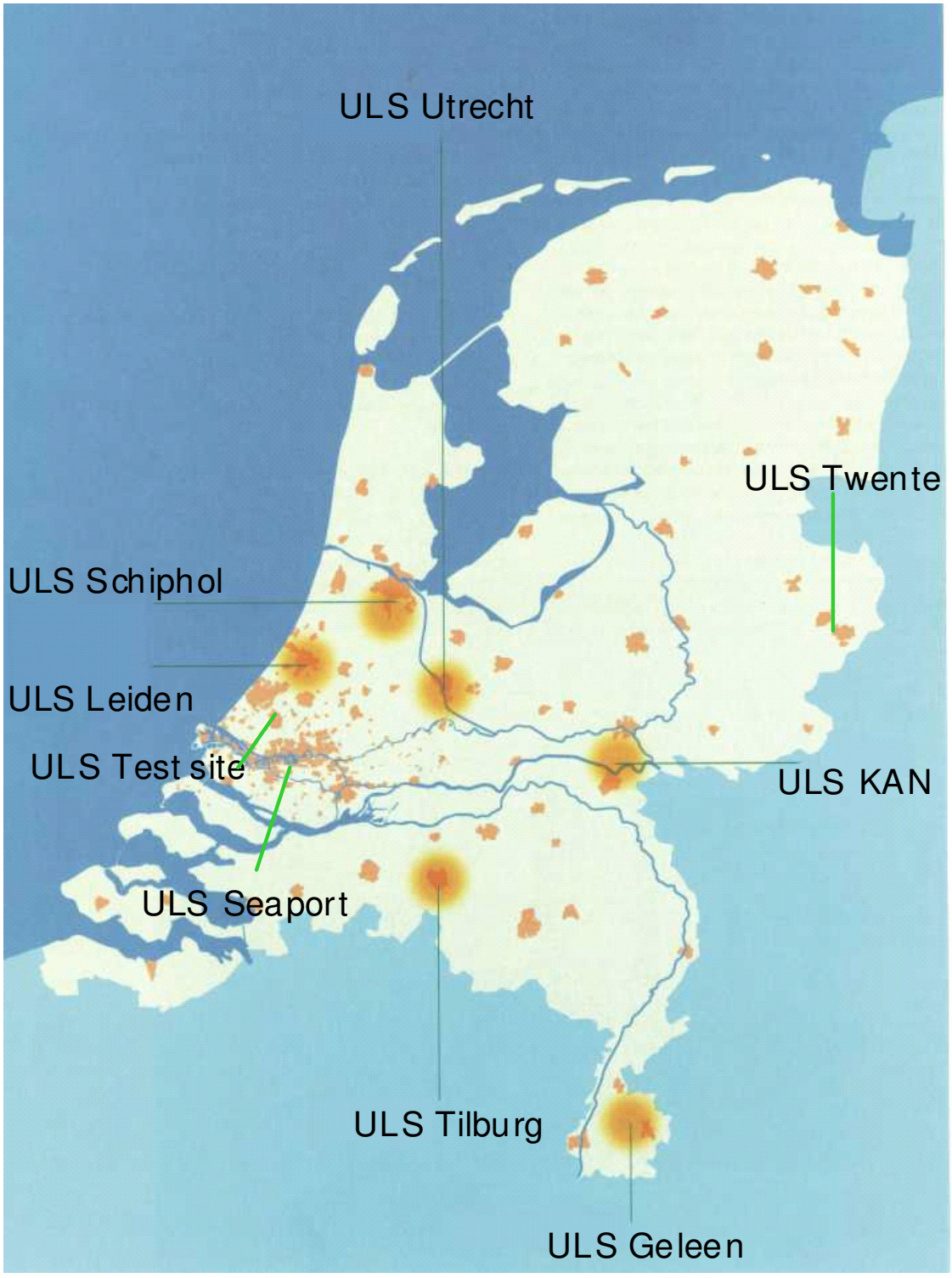

Figure 1: ULS projects in the Netherlands.
Source: Visser (1999).

The following applications can be mentioned (Visser and van Binsbergen, 2000):

1. In urban areas, for provisioning post offices, retail trade, catering establishments, office, and consumers. This application concerns the transport of load-units of pallet size. The feasibility of this application was researched in Dutch cities, (Utrecht, Leiden and Tilburg), in Japan (Tokyo), and in the UK (London).

2. Inside or between industrial complexes, logistical centres, and multimodal terminals, such as airport and harbour complexes. This application concerns the transport of load-units such as pallets, maritime containers and aircraft pallets. ULS Schiphol in the Netherlands is one example of this application.
3. Collection or long-distance transport of agricultural products, ore and solid waste. For this purpose, capsule pipelines have been developed and applied in Japan, the USA, and Russia.
4. Hinterland or cross-country transportation of maritime containers. Studies have been done in the USA but nothing has been put into practice.

ULS – as developed in the Netherlands – were in fact developed for the first two basic applications, but mixed applications are possible. The second application, the connection of industrial and logistical complexes to multimodal terminals, is intended to improve long-distance transport by rail or by inland navigation. Many of these complexes have no direct rail or inland navigation connection. A direct connection is often not possible. By establishing a ULS between these complexes and a rail or inland navigation terminal, an efficient, fast and relatively cheap connection can be provided, so that transport by rail or inland navigation becomes a realistic option.

(Dis)advantages

The concept combines the advantages of taking the traffic movements underground and applying electrical propulsion, with the economic advantages of unimpeded automated transport over a dedicated infrastructure that is separated from passenger traffic. The economic advantages are to be found in an almost direct delivery in the Schiphol area (no more need for round trips with mixed cargo), 24 hour service, relatively low variable and exploitation cost, and short turnaround times. Other advantages concern the lower (local) environmental burden, resulting in reduction of noise, visual pollution, and emissions, reduction of congestion problems, reduction of energy use, and a related reduction in CO_2 emissions, more intense use of available space, and an increase in traffic safety. On the other hand, a completely new underground infrastructure must be provided. This requires high investments, a long realisation time, and much fine-tuning with (local) stakeholders. However, the balance of the advantages and disadvantages was not decisive enough, and the ULS project was finally put on hold in 2002 (Pielage, 2005). The question therefore arises: Which barriers and enablers have influenced this decision?

3. The theory on the adoption of innovations

An ULS can be seen as an innovation, because an innovation is defined as an idea, practice, or object that is perceived as new by a unit of adoption (Freeman, 1989). Every innovation goes through an innovation development process (Rogers, 2003). Also in the case of ULS this process can be described in several phases: An ULS evolves (phase 1) from the recognition of the increasing level of congestion and air pollution caused by freight and passenger transport. This increase has led to a need for an alternative and more reliable (underground) transport system. Through applied research (phase 2) a new alternative (ULS) has been developed that under ideal conditions, contributes to reduced

congestion and emissions of hazardous pollutants. This ULS is first introduced in a so-called niche market such as the Schiphol area (phase 3) to demonstrate the concept. As a result of this niche market demonstration the technology can be diffused and adopted (phase 4) by other units of adoption. So far, no introduction has taken place and it is not to be expected that this will happen in the near future. In order to analyse this lack of adoption, ULS will be analysed with respect to three elements (based on Wiegmans et al, 2007 and Van der Straten et al, 2007): product characteristics; user requirements; and innovation system (the framework within which innovations are created). Adoption is the outcome of an innovation decision process to completely use the innovation as the most suitable option. This process is a mental one through which the unit of adoption passes from first knowledge of an innovation to a decision to adopt or reject that innovation (Rogers, 2003). This innovation-decision process, or process of adoption, has 5 different stages briefly discussed below. The knowledge stage occurs when the unit of adoption, in this case actors in and around Schiphol, are exposed to the ULS and gain understanding of how the ULS functions. If this knowledge is considered relevant to the unit of adoption than the persuasion stage can begin. At this stage, the units of adoption form a favourable or unfavourable attitude towards the ULS. Characteristics of the innovation are especially important at this stage. The next stage is the decision making phase. When the decision is made to adopt the ULS, the implementation stage follows directly. In the final stage, the confirmation stage, the adopter evaluates the decision taken to adopt the innovation.

On the basis of ten interviews with experts who were involved in ULS, we aim to reconstruct the recent history of ULS, in order to analyse enablers and barriers to adoption. An enabler for adoption can be seen as any aspect that stimulates the adoption of ULS by an adopting unit where ULS is not in operation (adapted from van der Straten et al., 2007). Clearly, a barrier towards adoption could represent any aspect that inhibits the successful implementation or realisation of ULS in a certain area. Most of the variance of adoption of innovations is explained by the five attributes of innovations (product characteristics): relative advantage, compatibility, simplicity, try-out (or trial ability) and opportunities to observe. Rogers (2003) deservedly defines the attributes of an innovation as 'perceived' because he thinks it is the receiver's perception of attributes of innovation and not the actual attributes as classified by experts that affect the ease of transferring. Innovation studies, literature and research widely support the influence and validity of these perceived attributes of innovation (Holloway; 1977; Moore and Benbasat, 1990; Kearns and Huo, 1992; Goldman, 1992). In this research, the perceived product characteristics (attributes of innovation): compatibility, simplicity, try-out, context consistency, and relative advantage are used in the theoretical model. In addition to the product characteristics, two other characteristics categories that partly explain the adoption of an innovation are added: 1) user requirements (the relative advantage) and 2) the innovation system. For transport research, the relative advantage is often 'translated' into quality aspects of transport (Wiegmans et al, 2007). Quality aspects that we consider for the ULS are (based on Wiegmans et al, 2007): reliability, costs, efficiency, flexibility, safety/security, speed, and catchment area. The innovation system that focuses on the support of different actors in the innovation system could have three different aspects that apply to the ULS (adapted from Brouwer et al, 1997): 1) project complexity; 2) project management, and; 3) clear goals. Together, these three areas lead to our research model that structured the interviews with the experts (see Figure 2).

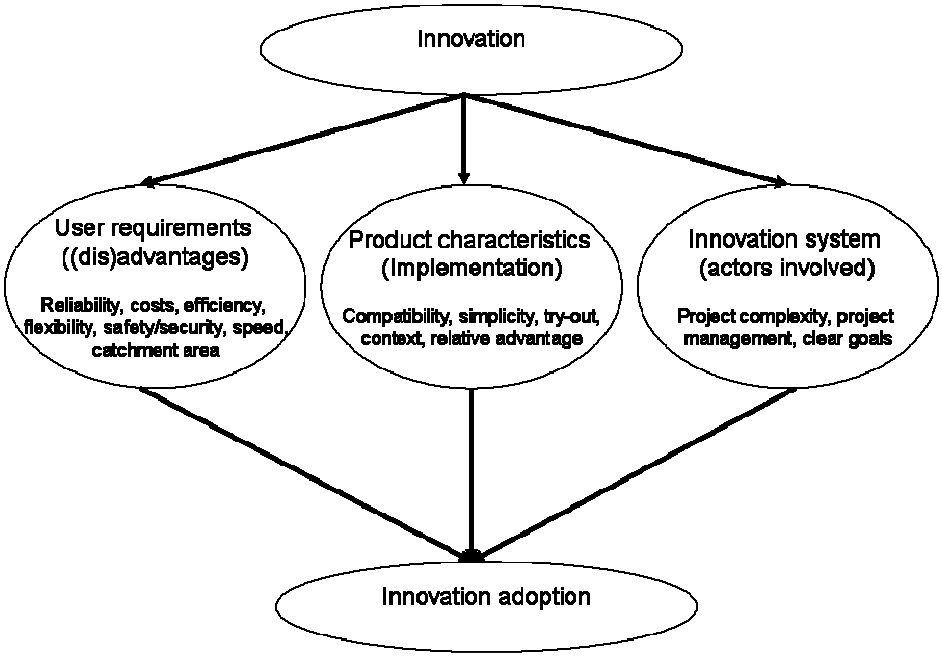

Figure 2. Research model
Sources: Based on Rogers (2003); Cardebring et al. (1999); IQ (1997); Konings and Ludema (2000); Wiegmans (2003).

3.1. Adoption of ULS: product characteristics

In this research study, the perceived attributes of innovation (product characteristics) – compatibility, simplicity, try-out, context consistency, and relative advantage – are used as the basis for the interviews and the ex-post evaluation. *Compatibility* refers to the degree to which an innovation fits into existing infrastructure (technological). The degree of compatibility of an innovation, as observed by the actors involved, correlates positively with the degree of adoption of this innovation. An idea that is more compatible is less uncertain to the potential adopter and fits more closely with the situation of the individual. Diffusion research suggests that compatibility may be a little less important in predicting the outcome of the decision to adopt than the relative advantage (Rogers, 2003). The ULS is technologically different from the transport modes already in operation. To determine whether or not the compatibility with the infrastructure is an enabler or barrier one has to look if changes have to be made to the existing infrastructure, and thus if supporting infrastructure has to be built. *Simplicity* is the degree to which an innovation is perceived as relatively easy to understand and use (Tidd et al., 2001). The simplicity of an innovation, as perceived by members of the system, is positively related to adoption. In general, simplicity is less important than relative advantage or compatibility (Rogers, 2003). ULS might be based on a different kind of technology, which is new to the freight transport sector. When ULS is easily understandable and no new knowledge is needed, then this can be seen as an enabler for adoption. *Try-out* refers to the degree to which an innovation can be experienced and tested (Rogers, 2003). Try-out is the degree in which an innovation can be experimented with on a limited, free of charge or no cost basis (Tidd et al., 2001). The try-out opportunity, as perceived by members of the system, is positively related to adoption.

The possibilities to 'try out' an innovation, as perceived by members of the system, is positively related to adoption. The variable *context consistency* is defined as: 'the degree to which ULS is perceived to be consistent with the existing values, experiences from the past, the needs of potential users and beliefs in the context of freight transport' (Rogers, 2003). The *relative advantage* can be seen as the degree to which an innovation is perceived as better than the product it replaces, or competing products (Tidd et al., 2001). Relative advantage has been found to be one of the strongest predictors of the outcome of the decision on whether or not to adopt. The relative advantage of an innovation, as perceived by members of the system, is therefore positively related to adoption. The nature of the innovation determines what specific type of relative advantage is important to adopters. In this study, we do not take the relative advantage as a separate attribute, but we operationalise it through the user-requirements.

3.2. Adoption of ULS: user requirements

The success potential of innovations must be determined in order to select the most promising innovations. A second category of characteristics that determine the success potential are user requirements. The user requirements for ULS will have to do with changes that lead to a better transport quality. The main drivers of transport operations are costs, reliability, and speed (Wiegmans, 2003). The implementation of ULS probably also strongly depends on improving these drivers. Several other criteria can be found in transport research (Cardebring et al., 1999; IQ, 1997; Konings and Ludema, 2000; and Wiegmans, 2003): reliability, costs, efficiency, flexibility, safety, speed, space saving, and automation. Worrell et al. (1997) mentioned fuel efficiency and costs as general success criteria. Hekkert and Harmsen (2001) used system dependability as a criterion to compare innovations. Tsamboulas and Dimitropoulos (1999) identified the nodal centre's size, catchment area, and the level of political support for the investment as the main decisive factors for choosing the appraisal method and decision criteria for investments in container terminals. The following criteria have been selected to analyse the user-requirements: reliability, costs, efficiency, flexibility, security/safety, speed, and catchment area. Reliability is the degree to which ULS meets the agreed service time. Innovation costs are the investment costs involved in purchasing ULS and the exploitation costs incurred after purchase. Efficiency refers to the degree to which ULS is able to perform the operations efficiently (as compared with truck transport). Flexibility is the degree to which ULS is capable of solving problems for customers when they arise. Safety/security refers to the safety and security of ULS. Speed refers to the number of load units per time unit that ULS is capable of handling. The catchment area of ULS refers to the average distance of the shipments that ULS might be able to attract.

3.3. Adoption of ULS: the innovation system; actors and project management

In the beginning of the Governmental task force IPOT, meetings were held with national and international experts, and the literature was reviewed to define the critical enablers of and barriers to the innovation system of ULS. From experiences in Japan it was learned that it is important to involve the right stakeholders in the process and, in particular, an influential private stakeholder as a driving force. Innovations, from Sony's

Walkman to Toyota's Prius show the importance of a stakeholder, who believes in the innovation and acts as the driving force. The other critical factor was learned from earlier innovation projects in the field of transportation, such as combi-road (an automated transport system for moving containers on road and rail over longer distances), and can be described as 'support from society'. Social and political support is greater when people and politicians actually know and are able to see that the innovation works and performs as promised. The third critical success factor requires that the right conditions are created for successful implementation (van Binsbergen and Visser, 2001). Society is built on the basis of current transport systems and is seldom ready for new revolutionary innovations. In order to fulfil these success factors Brouwer et al. (1997) described the implementation strategy for ULS in urban areas. Derived from this framework, innovation management system characteristics that have been selected for the analysis are: project complexity, project management, and clear goals. Project complexity: The complexity of a project depends on different factors, such as the required functionality of the design, the conditions in which the product has to perform, the number and type of actors and the required technologies. In order to show the difference, a total redesign of a transport system is a much more complex and ambitious project to manage than, for example, a new design for an existing car type. Project management includes complementarity, multidisciplinarity and competence. A critical success factor for an innovation trajectory is project management and the available skills in the project team. Complementarity and multidisciplinarity within and between project teams are key words. The competence of the team members or the members of an industrial consortium are a key factor. Clear goals: Innovation projects often fail because of vague or unclear project objectives, too many objectives, or objectives that change during the course of the project. Setting objectives is important. It focuses the project on specific aims over a period of time and can motivate staff to achieve the objectives set.

4. Ex-post evaluation of barriers and enablers

The ULS-project (Schiphol) is well documented in terms of feasibility studies, design studies and project reports. No ex-post evaluation has taken place since the project was halted. As a first effort, this evaluation is based on ten interviews with employees from firms of consultants, engineering companies, industries, universities, and responsible authorities at the national Department of Transportation who were involved in the project.

4.1. Analysis of the product characteristics

From the theoretical framework, the characteristics compatibility, simplicity, try-out, and context consistency will be evaluated. ULS Schiphol was largely based on proven-technology to make it compatible and was designed as a dedicated, solitary system for freight. This means the semi-continuous transport of smaller amounts of standardised load units 24 hours a day in an enclosed environment. Much attention has been given to make the system compatible with load units that are traditionally used by the shippers (AC pallets, roll cages). Less attention was given, however, to the connecting

infrastructure and to the availability of sufficient freight volumes. Particularly in the beginning, the system must operate as link in an intermodal system. Only in a limited number of situations, referred to as the 'niche-markets', is it possible to build a door-to-door ULS. Transhipment is needed which reduces the overall performance of the ULS and is an important cost factor. Therefore, it also became quite a design challenge to create the right transhipment facilities for ULS. The solution was found in automating the transhipment process. However, it has never been tested in pilot projects to see if it actually worked. Overall, the respondents perceive compatibility neither as a barrier nor as an enabler to successful adoption.

Although the overall concept of ULS was complicated, it was reasonably easy to understand (simplicity), despite the fact that part of the design was based on quite innovative technologies. Existing technologies combined with new technologies provided the basis for a totally new system. The new technologies were partly based on upscaling existing automated transport systems, such as the AGV-technology used at ECT seaport terminals in Rotterdam and the smaller AGVs in automated distribution centres. Much energy has been put into visualising the concept (3-D graphics and simulation, etc). Overall, the respondents perceive simplicity in a mixed way. The perception 'neither as a barrier nor as an enabler to successful adoption' has the most support from the respondents, followed by 'barrier'.

Try out possibilities for the ULS-system were considerable, although the complete system has never been built. The opening of the ULS test site where trucks were tested was a good start but it never came to a complete real-life pilot. The test site was very helpful in testing parts of the system but a pilot should be more than testing the technology: the system should have to prove itself in a real life situation with real users. The costs acted as the main barrier to set up a real and fully operational pilot of a complete ULS system. According to the respondents, try-out possibilities acted as a barrier for the successful adoption of ULS.

The context consistency acted as a barrier. The freight transport and logistics industry is a relatively conservative and very competitive industry with many small and some large companies with rather low margins. The freight transport industry showed a limited interest in the ULS-projects. There was a lot of public attention and interest from national, regional and local public authorities. According to the respondents, more could have been done with respect to the political aspects; one of the main problems indicated is that the political decision makers should have been involved at much higher levels than was the case at that time. From a technological point of view, ULS was the next phase in automation within the logistics supply chain. However, for the period concerned, ULS was maybe a little too 'modern'.

From the interviews, it can be concluded that compatibility and simplicity neither acted as a barrier nor as an enabler (see Table 1). In order to increase the chances for the successful adoption of ULS, the compatibility and/or simplicity should be improved. Try-out possibilities clearly acted as a barrier for ULS Schiphol. Several separate parts of ULS Schiphol have been developed and tested. However, a complete real-life system has never been built and tested. The context consistency also acted as a barrier. The ULS system was maybe rather too sophisticated in the time period concerned. Furthermore, the political support should have been gathered on a higher level.

Table 1: Interview results of the product characteristics.

	1	2	3	4	5	6	7	8	9	10
compatibility	E	B	0	0	0	0	0	0	0	B
simplicity	B	E	B	0	0	0	0	B	E	B
try-out	E	0	B	B	B	0	B	B	B	E
context	B	B	0	B	0	0	B	B	B	B

Notes: E = enabler; B = barrier; 0 = neither barrier nor enabler (neutral).
Source: 10 interviews were held with Ondergrondse Logistieke Systemen experts.

4.2. Analysis of the user-requirements

In theory, ULS performed rather well compared with existing freight transport modes. An important issue was (and still is) that it was unclear how these advantages would be valued by the proposed future customers. ULS Schiphol performed well in terms of reliability. This was clearly an enabler for the system. The main points of concern were occasional disruptions and maintenance. Calculations showed that the high number of vehicle kilometres driven every day would cause a disruption once every week. Given the high capacity of the system, this was acceptable. However, for the customers it would be a problem to have a disruption once a week.

The investment costs in tunnels were too high, in particular because these costs could not be shared with other users, as is the case with other transport modes. It was expected that the government would finance the investment costs, but that did not materialise. This led to an overall cost picture that was unacceptable to both political and private actors. ULS performed quite well in terms of operational costs. On average, calculations showed that the costs were 25 percent below those of a road transport service (with a depreciation period of 50 years). A main problem in the cost area was that the project was perceived by many involved actors as a technological project and the economics were not perceived as an equally important issue.

Improving the overall efficiency of freight transportation was an important objective. The tests showed that the system performed well. Even the loading and unloading, one of the major concerns, performed well. The actual loading and unloading had to be measured in seconds rather than minutes as was first expected. Overall, the respondents perceive this neither as a barrier nor as an enabler.

In itself, the system was quite flexible. It was an open standard and many different loads could be transported. However, the construction time and the long-term investment in the infrastructure made it quite inflexible compared with road transport. Overall, the respondents perceive this neither as a barrier nor as an enabler.

Much attention was paid to safety and security issues. Protocols were designed. Because of the enclosed environment, the system performs better than existing transport modes. Overall, the respondents perceive this neither as a barrier nor as an enabler.

The maximum speed of 30 km/h was no limiting factor to compete with single/mode road freight transport over relatively small distances. At these distances, speed is not an issue. The respondents perceive speed either as an enabler or as neutral. At longer distances, longer travel times will be compensated by higher reliability and demand availability.

The catchment area of the ULS Schiphol was limited. According to the respondents, the catchment area acted neither as a barrier nor as an enabler. The project area has been

redefined many times: about 40 different versions of ULS have been developed. It proved that the 'total open airport' was the best solution. Ultimately, the freight volume was too limited and the connections with rail (and barge) were not sufficient. Therefore, in the end, we perceive that the geographical coverage acted as a barrier for ULS.

To summarise the user requirements, the barrier to ULS Schiphol was costs (see Table 2). This shows that one main important criterion for freight transport solutions (costs) did not favour the successful implementation of ULS Schiphol. Enablers for ULS Schiphol were: reliability and speed.

Table 2: Interview results of the user-requirements.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
reliability	E	E	E	E	E	0	E	E	E	B
costs	B	B	B	B	B	0	B	B	B	B
efficiency	E	0	E	0	0	0	0	0	0	0
flexibiity	E	0	0	0	B	0	0	0	0	B
safety/security	0	0	E	0	0	0	0	0	B	B
speed	E	0	E	0	E	0	E	0	0	E
catchment area	0	B	0	0	B	0	0	0	0	0

Notes: E = enabler; B = barrier; 0 = neither barrier nor enabler (neutral).
Source: 10 interviews were held with Ondergrondse Logistieke Systemen experts.

4.3. Analysis of actors and project management

The project was financed by the Ministry of Transport and Waterworks and supervised by other Ministries participating in the interdepartmental project team (IPOT). The airport authorities, the VBA (flower auction Aalsmeer) and the rail operators also participated. However the main 'working' actors were researchers from firms of consultants and universities. The government turned out to be the only real driving force behind ULS. The Ministry of Transport set the condition that the private sector should participate and take the lead in the project as financer. During the project, it became clear that the private sector had only shown interest but had no intention to really participate financially in the project. Other actors, such as the transport industry were also not involved and neither were the high level decision makers. Probably the lack of a real sense of urgency among the high level decision makers played a role in the lack of success of ULS.

Many actors participated in the project making it a complicated project. But, according to the respondents, the project complexity was neither a barrier nor an enabler for the success of the ULS system. There were too many institutions involved with too many interests, different goals and different ideas about ULS. Also the dynamic surroundings at Schiphol, with a new runway (Kaagbaan) made it complex.

The mix of different institutions (private organisations, universities and consultants) in the ULS project all with different interests made it complex but at the same time guaranteed a multidisciplinary group of team members with complementary competences. Several respondents indicated that the team was too large and also that team changes influenced the progress and stability. The project was managed well with milestones and strict deadlines. The other ULS-projects were smaller and only one or

two consultants were involved. According to the respondents, this was either a barrier to the successful adoption or a neutral factor.

The main objectives (clear goals) of the project were basically two: the first was to develop a knowledge (R&D) on automated (and underground) freight transport. The second one was to implement ULS. But also policy objectives, economic as well as environmental played a role. According to the respondents, there were clear barriers for the successful adoption of ULS. There was a lack of one central goal shared by all actors. First the idea was to build an underground system, but later on this changed to ground level. Furthermore, there was no owner of the problem and an insufficient sense of the urgency.

Table 3: Interview results of the project management.

	1	2	3	4	5	6	7	8	9	10
project complexity	0	B	0	0	0	0	B	B	B	B
project management	0	B	0	B	0	0	B	B	B	B
clear goals	E	B	B	0	B	B	B	B	B	E

Notes: E = enabler; B = barrier; 0 = neither barrier nor enabler (neutral).
Source: 10 interviews were held with Ondergrondse Logistieke Systemen experts.

To summarise the project management, barriers to ULS were: clear goals and project management (see Table 3). The other factor (complexity) seems to be neutral for successful ULS adoption.

4.4. ULS Spin-off

Until now, ULS has not been implemented in the Netherlands. This means that there are no direct spin-offs of the ULS project. However, the project stimulated considerable academic and private research, received support from different local and regional governments and gained public attention. Therefore, the research and attention will have generated some spin-offs. Possible knowledge spin-offs are: i) automated transport technology; ii) terminal technology; iii) logistic concepts; and, iv) tunnelling technology. One spin-off mentioned is the implementation of knowledge about AGV-technology in the people-mover project at the Rivium (Rotterdam, the Netherlands). The experience with the test site has been used by TNO for their new test site. The ULS studies stimulated the thinking about unmanned transport and innovative transport systems (for example the cargotram). Much has been learned about prototyping, modelling, simulation, and testing of automated freight transport. The ULS project initiated the thinking about new logistic systems in the Netherlands, such as agrologistics. Knowledge on underground construction is being applied at the Euromax terminal in Rotterdam. It has also drawn attention to traditional pipeline transport and to new initiatives (the multicore pipeline at seaport Rotterdam, and the ethylene ring pipeline in Northwest Europe). The project has been important for the personal knowledge development of many students (Masters, PhD), researchers and consultants. The knowledge is further used in other areas (national and international). A considerable number of articles have been published and papers presented at international conferences. The project has been important in promoting Dutch research internationally.

5. Conclusions

The research question in this article was: Which barriers and enablers have led to the failure of ULS and what ULS spin-offs can be found nowadays? The research question has been answered using the theoretical model that served as the basis for the interviews with the experts. If we consider compatibility, simplicity, try-out, context consistency and the relative advantages of ULS as possible success or failure factors, then some conclusions can be drawn. On the basis of the interviews, it can be concluded that compatibility and simplicity acted as neither a barrier nor an enabler. Try-out opportunities and context consistency acted as a barrier. ULS was largely based on proven-technology to make it compatible and was designed as a dedicated, solitary system for freight. However, ULS was less compatible with the outside (Schiphol airport) infrastructure. Therefore, only in a limited number of niche-markets is it possible to build an ULS-system. The overall concept of ULS was complicated but also quite easy to understand. Existing technologies were combined with new technologies and provided the basis for a totally new system. Try-out possibilities for the ULS system were too limited. The opening of the ULS test site where trucks were tested was a good start but it never came to a complete real-life pilot. The context consistency acted as a barrier. The political support of the important political decision makers was lacking and so was support from the private sector in the field of logistics (transport companies and the large shippers). The lack of support from the private sector was the main reason why political decision makers discontinued the projects.

The main conclusions from the user requirements are that the main barriers to ULS Schiphol are costs. An important enabler for ULS Schiphol was reliability and speed. Although the variable costs were considered relatively low compared to existing modes the investment costs were high. The total costs immediately put ULS at a disadvantage as compared to the truck. The catchment area was neutral in its impact on successful adoption. The area was too limited, and the connections with rail and inland waterways were limited, which meant a reduction in potential freight volumes. The reliability of ULS was a clear enabler. The system was very reliable, although, given customer requirements, a projected failure of every once per week can be perceived as considerable.

The main conclusions for project management are that barriers to ULS were clear goals and project management and the other factor was neutral for successful ULS adoption. In the ULS-project, many actors were involved having many different interests, goals and ideas. Although this made the project more complex, these factors were not critical for it. However, the lack of a real owner of the problem, a ‘Mrs ULS’ who should have been the driving force in the project, was a serious issue. The lack of a clear goal and changes in the other goals also acted as a barrier.

Although the ULS-project has not been implemented, the investments have resulted in spin-offs. The beneficial effects seem to be taking take place in different directions: ranging from rather soft impacts (scientific knowledge elaboration and dissemination, mapping the innovative image of the Netherlands, encouraging thinking on innovative transport and logistic solutions, increased attention for conventional pipeline transport policy) to more hard developments (adopting and developing transport and tunnelling technologies) and, although difficult to quantify, they are of great value. In the final analysis, perhaps the most valuable spin off remains the ‘learning experience’: the knowledge about which barriers to overcome and to make the most of the enablers of

the ULS-innovation process as they have been experienced. This should be a major asset if the development and implementation of ULS is to be successful in the future.

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