REDUCING CO2 AND COSTS BY USING THE SPACE UNDER SEMI TRAILERS TO CARRY 31% EXTRA CARGO ON PALLETS UNLOADED VIA THE BACK DOORS

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Abstract
Using the space under a standard size semi-trailer to carry extra cargo loaded via the back doors, this semi-trailer will save circa 150,000 kg/330693lbs of CO2 and circa $USD 70,000 costs per trailer per year, reducing traffic and the number of trucks and drivers required in a sustainable supply chain. Given in logistics the efficiencies of using loading docks/bays by distribution centres and large retailers this design uses existing trucks, loading equipment, loading bays and infrastructure. It can be used globally. With the addition of a tail lift it can serve places where load bays are unavailable. This new semi trailer design uses new to the trucking industry technology, with 20+ granted patents.

Keywords: Sustainable supply chains, Logistics, Semi-Trailer, Trucking, High-Capacity trailer, Heavy Vehicles, Eco-freight, Green freight. Efficient road freight transport, Driver shortage, City trailers. Symposium

1. What problem? Stopped in traffic on the motorway I saw the space underneath the semi-trailers next to me and asked why aren't heavy vehicles fully using that deep space? Research found there was no mechanical way to move the cargo out through the back doors.

2. Introduction: global view.
Heavy Goods Vehicles (HGV) traffic globally is at its highest levels ever and set to increase as developing countries catch up with the advanced economies demanding more infrastructure, fuel and thereby producing more traffic, more costs and more pollution (OECD, Freight transport (indicator) 2021)

In Western economies driver shortages are also a growing challenge. (IRU, Driver shortage: a global issue, 2021)

Besides increasing heavy vehicles' mass and dimensions, one response to the freight growth has been to increase the load capacity per trailer and per journey. Increasing trailer capacity ideas include mezzanine floors accessed from the trailer side or having a fixed or moving deck and independent suspension units. But these are difficult to use at distribution centres, expensive and require specialist equipment/loading bays or are illegal for frozen food transfer in Europe. By contrast, the design described in this paper requires no changes to logistics infrastructure as it uses conventional trucks, axles, tyres, loading bays and loading equipment. This trailer design includes a new technology which focuses on those loads where capacity is reached before legal weight is met.

It is crucial that the trailer meets existing legal dimensions for the majority globally, i.e. 4m/13ft 2in, 13.6m/40ft long and 2.6m/8ft wide in Europe. The USA allows higher and longer - 16.5m /53ft long and up to 4.11m/13ft.8in wide.

Lifting system, moving decks and controls, a brief history

SOMI Trailers in-house R&D unit tested various methods to solve the lifting challenges. Including: using hydraulics; scissor lifts; cable systems and latterly, air bags.

Ways of creating a mechanically operated series of moving decks, to enable unloading by hand or with a forklift truck or pallet truck for various cargoes were explored. The criteria was that an uneducated person could be trained in a few minutes to unload or load with an on-board computer controlling all the deck movements once initiated by an operator. Exploration in depth and creation of full-scale prototypes followed. The first idea used hydraulic rams to raise and lower the central platform. This proved unsuitable as the hydraulic systems always have leakage over time. Next, scissor lifts were utilized with high pressure airbags but the inherent danger and inconsistent performance of the airbags due to friction was unsuccessful. Next, electric motors winding cables to raise and lower the decks worked, but the initial cable stretch and subsequent inherent stretch meant that the decks could never be levelled as the cargo weight would be unknown and be varied.

3. Proposal:
Increase trailer productivity while reducing CO2 emissions by utilizing the space underneath a semi-trailer to carry cargo accessed from the rear doors.

User friendly equipment is of great importance, due to the pressure on time and many varied uncontrollable events in logistics such as weather, traffic delays, and low profit margins as a fragmented industry. From initial construction, loading and unloading, maintenance, environmental impact, capital outlay, costs and control by management have been considered. For example the criteria was used that a female/below average build person could load the trailer by taking a wheeled based unit over any deck joint, as all floors would be level.

Figure 1. A SOMI trailer as built. Source: authors own 2020

3.1 Proposed method:
Utilize the space underneath a trailer by incorporating it into the body. The idea requires a central deck to lower in the space underneath. Then the rear area has two decks, the top one being lifted by the lower to a point where it engages with internal walls ready to move forward. Next the lifting deck below lowers to a new level ready for loading. Last the deck now engaged on the internal rail moves complete with its own internal wall forward to a designated stop.

Figure 2 below shows how the system works. The animation is available at somitrailers.com

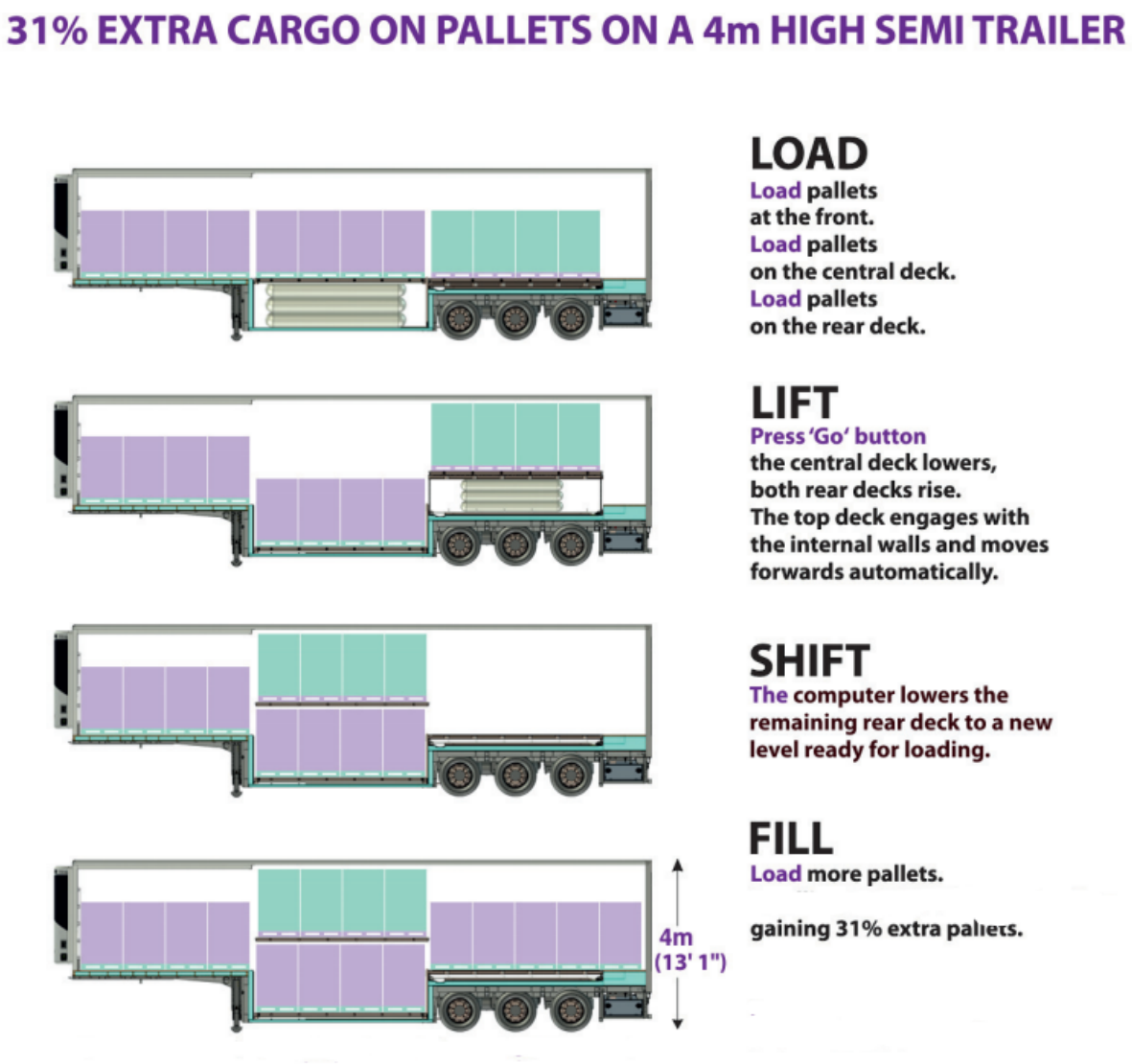

Figure 2. Loading sequence for a trailer that utilizes the space underneath to carry extra payload

3.2 Prototyping

Lifting system, moving decks and controls

The successful method employs airbags working at low pressure, 3.4 PSI (0.234 bar) to lift 7,200kg/15,875lbs with sensors advising the on-board plc (computer) of the decks arrival and sharing this information by a simple traffic light indicator panel inside the trailer.

Figure 3. Rear view showing the usable space available. Source: authors own 2020

Results:
The resultant mechanism and software have been developed, creating a fully operational trailer carrying 8 extra UK/USA (10 EU) pallets, with EU type approval granted and successful onsite trials on a commercially built unit over a 2-year test period.

Testing the Lifting system
Numerous designs of air bag underwent trials and tests and the last iteration produced with the deck, passed the LOLER test lifting 7,200kg/15875lbs at 3.4 PSI (0.234 bar). Monitoring performance is by having an on-board modem, enabling data to be mined to improve and report on performance. It can also report location, doors being opened, internal temperature, CO2 levels and other data. The mechanism is operable remotely by appropriate staff to override and make adjustments in the field with the onboard plc and messaging unit. The mechanism is powered by 4x 220 amp hour batteries on board, recharged by photovoltaic panels on the roof or the truck accessory connection or to an external supply. Tail lift or other accessories can also be powered.

Figure 4. Rear view showing rails and rolling walls in a refrigerated trailer. Loading bar rails run the full length above the mechanism. A tail lift is fitted to this reefer version. Source: Authors own 2020

4. Results:

Safety

A key factor in the industry for both people and cargo, with 31% fewer journeys it is expected to reduce truck related accidents. A safety belt at the rear has to be in the engaged position for

the mechanism to work, if mid cycle it is removed the mechanism immediately stops and holds its position. Calculations by the body builders Paneltex show a lower center of gravity at 1.1m/43in as opposed to the average 1.5m/54in for the same trailer without the well area. This may improve its Standard Rollover Threshold -SRT-, however in use data is needed to evidence this improvement.

Figure 5. Inside a trailer, showing the safety belt at rear. Source: Authors own 2020

Manufacture

The design has been productionized to aid rapid production and therefore faster adoption. The body has European type approval and can be built on every continent. The body has been designed so that the mechanism can be installed at a different location with no further visits to the original bodybuilder. The mechanism can be shipped in parts to enable assembly globally. The design has also been adjusted for ease of maintenance by, for example, removing all parts that needed lubrication and replacing them with self-lubricating components; all painted surfaces internally have been replaced with stainless steel or aluminum.

Fuel used

Fuel trials by BTAC on a UK test track showed a circa 1% saving in fuel used over a days testing, possibly due to the aerodynamics of the lower area; further work is needed to define how the saving occurred. The same test using a comparator trailer identical except for the well area from the same manufacturer and equally loaded was used.

CO2 emissions in freight transportation is partly a result of fuel used. By using 3 journeys instead of 4 this saves the fuel and consequential CO2 by 25% over 3 journeys. Also, saving CO2 from production costs and other in use costs such as tyres, have not been estimated here. According to Transport 2020, a truck produces 450,000kg CO2 per year. This equates to a saving of circa 150,000 kgs of CO2 per year per trailer if used once a day, 7 days per week for

50 weeks a year. As a comparison a car produces on average circa 5,000kg of CO2 (EPA Green Vehicle Guide 2018).

Ground Clearance
The trailer height above the road can be raised by using the on-board suspension to increase clearance from the normal 200mm/7.87in to 500mm/15.74in when loading on ferries or in adverse road conditions. This meets the EU regulation of 190mm/7.48in. clearance.
The trailer passed the humpback bridge test at a UK test track.

Dimensions
For the mechanism design, trailer dimensions are not critical for height or length but for width markets such as Australia at 2.5m/8ft2in would need addressing as after loading pallets the space for the internal walls and mechanism would be insufficient. The mechanism requires 50mm each side, this can be addressed by legislation. Other markets can adapt as local requirements demand. A short version carries 6 or 8 extra pallets at 11m/36ft long.

Weight.
Unilever stated their average pallet weight is 600kg in Europe.
Therefore 34 pallets x 600kg (1322lbs) is 20,400 kgs (44975lbs) load. Given a truck weighs circa 7,000kg (USA 15,400lbs) (Volvo, 2021) the trailer is less than the remainder and within the 40,000kg maximum. (USA 88,185lbs).
Laws already require operators to manage weight compliance, so no additional work is created meeting this requirement.

ROI (Return on investment)
The initial cost over a standard trailer is increased. With use once per day, 7 days per week, 50 weeks per year ROI (return on investment) is achieved in circa 12 months. Tolls and ferry fees are the same but for more cargo, saving costs, making profit.

Table 1 - Summary examples for the gains per pallet delivered in GB£/USD$

Example 1	1 journey per day	7 days per week	50 weeks per year	8 extra pallets per load
GB£/USD$	25	30	35	40
Gain per year	70,000	84,000	98,000	112,000

Example 2	2 journeys per day	7 days per week	50 weeks per year	8 extra pallets per load
GB£/USD$	15	20	25	30
Gain per year	84,000	112,000	140,000	168,000

Patents
20 patents have been granted on several continents, as the loading arrangement was identified as unique and worthy of "an expert in this field." More patents are applied for and pending.

Flexibility
The trailer can be used as a normal trailer when required, e.g. heavy or non-palletised loads. It has also been developed as a refrigerated unit to both ATP class A (chilled) 0-6 degrees C and Class C (Frozen -18 degrees C) or can carry ambient loads. No additional trucks or changes to infrastructure are required. Tail lift short versions for city deliveries. Tail lifts have to be column type due to the space occupied by the control boxes and barn doors are preferred. Using cargo restraint bars, the trailer can run with less-than-full loads. The ability to run with a conventional flat deck to accommodate heavy or larger dimension loads creates flexibility.

5. Potential future impacts:

Infrastructure projects may be delayed or downsized as fewer journeys are required, CO2 and cost savings expected from motorway and road building is not calculated here but is expected to be considerable as 7% of global CO2 emissions come from cement production. In terms of infrastructure usage and traffic, in the UK if 50% of loads used this extra capacity it could remove a line of 11,000 trucks parked nose to tail around the M25 ring road of London, some 117 miles/188km every day and still deliver all the goods. (Department of Transport, UK 2021)
Monetary savings such as less food transport costs. 30% of goods moved by road in the EU, more in developing countries, potentially produces a profit or reduced costs circa 5%.
In the EU 30% of the retail food price accounts for logistics, 20 to 25% of this is attributed to transport of food, the resultant saving of one in 4 journeys equates to a profit or saving of $70,000 per annum, $240 per load one way is equivalent to 5%. Hence the retailers who currently have an EBITDA of 2% or 3% have a potential profit increase on food of 4%.
Retail non-foods are expected to reduce CO2 and other costs by using the space underneath.

Storage
Less in storage results in less infrastructure such as warehousing required, this is especially impactful on cold stores as the cost of storage is considerable in both CO2 and money.

Traffic: Fewer trips into cities reducing noise and congestion, accommodation of growth in the short term is expected. Reduced storage and other infrastructure requirements. Release of space currently used as loading bays in cities and elsewhere for alternative use. Seasonal peaks such as New year, Thanksgiving, Christmas and other festivals create huge problems for the logistics industry and having extra capacity can also save dash vans or milk runs.

Driver shortage and other savings
In the EU and USA, the driver shortage and increased cost of agency (temporary) drivers at higher costs are increasing. Drivers are in short supply in parts of Europe and the USA. (IRU, Driver shortage: a global issue, 2021)
Fewer drivers save on salaries, training costs and supporting roles. Potentially fewer bays are required. Costs of loading crews required are more relevant for advanced economies where each bay has a dedicated crew. In the UK a loading crew is allocated per bay, therefore as

fewer bays are needed there will be savings. An exercise we carried out at a UK distribution centre showed that as it takes 40 mins to arrive and unload - 15 mins is checking in and docking at the right bay and handing in keys and 5 mins at the end to leave. In our tests, it took 5 minutes to load the extra cargo. If ready on the loading bay then 8 extra pallets will in the course of an 8 hour shift have 10.6 loads to move 362 pallets instead of the usual 12 loads that carry 312 pallets, making efficient use of the loading docks by unloading the extra cargo through the rear doors. Equivalent amounts of non palletised goods also save time and costs. Back-office costs including people, delivery notes and other paperwork are reduced as 4 loads are replaced by 3.

Monitoring in use
Monitoring the onboard batteries and modem, monitoring of various data, the mechanisms and trailers performance and operational use is insightful immediately and long term. Maintenance can be anticipated by logging times and temperatures of motors, number of lifts and and other events, resulting in data, including events outside expectations.
Potential issues (for example, with a sensor) can be traced and if there is a supplier issue, tracked back and all vehicles fitted with that batch can be exchanged before failure. Remote management can be useful, for example if an electrical motor is running hot it can be slowed and fixed when back at base. Monitoring events such as the rear doors being opened can send an alarm signal to a manager's desktop so theft or illegal activity can be ameliorated. The ability to monitor temperature inside the trailer is valuable, for example carrying high value medicines or temperature sensitive cargo such as fresh flowers or fruit. The driver can be contacted who can then address the issue. Having a plc and power source allows monitoring of CO2 or other gases inside the trailer and messages sent when set parameters are exceeded.

Fuel
Fuel efficiency will be improved per pallet or cargo for any journey regardless of fuel type used by utilizing the space underneath a semi-trailer needing fewer journeys. Tests by BTAC at a test track in the UK against an identical trailer without the well area, showed a small (circa 1%) saving in fuel when loaded with the same weight. Availability and efficient use of fuel is unequal globally. Availability is particularly relevant for parts of Asia and Africa. It is a finite resource and CO2 is produced when fuel is transported.

6. Challenges

Reduced number of drivers required whilst creating profit also creates unemployment. Fewer loading crews, office staff and back-office employees may be needed.

The benefit to trucking companies may be reduced when adopting money saving initiatives because powerful customers, such as large retailers, who often insist on a "marriage value" i.e., reduced charges with no capital input when asked to make a change to their operations to employ new innovations, even if at no or low cost to them and of great benefit to the wider environment. Therefore, it may require government intervention to change the status quo.

Owner-drivers' ability to finance a new more expensive technology may be a challenge. Retrofitting in existing trailers is not possible as the chassis and walls are unfit for purpose. As with any disruptive technology there will need to be a strong uptake and assimilation into

operations departments as well as logistics. This would involve altering the software to anticipate the extra cargo space available and some re-routing as journeys may involve a double drop instead of two separate journeys. The delivery of more cargo will need extra space at the point of loading and delivery if cargo is laid out in advance.

7. Conclusions:

Increasing efficiency is one of the key factors for a sustainable supply chain. Reduction of CO2 emissions together with cost of transport reduction and increase in operations safety is one way of achieving this efficiency. The SOMI trailer improves consolidation, reducing the number of trips and vehicle kilometers besides yard movements. The conclusions of this paper can be summarised as:

- **Focus on reducing the number of journeys** is imperative to reduce all costs, both monetary and environmental.
- **Utilizing the space underneath has the potential to save CO2 and costs of many kinds globally.** Also, there is potential to save driver numbers required and reduce traffic as more load is carried per truck movement.
- **Food supplies at peak times** such as holidays, pandemic and severe weather can be increased by 30%
- **Security of supply** may improve as, for example, more is carried per ferry crossing
- **With no infrastructure changes** or changes to existing trucks -such as loading bays- there are obvious advantages compared to alternatives such as extra high trailers.
- **Compatibility** with future trucks using any type of propulsion is an immediate advantage.
- **Large scale use** and trials and subsidized or soft loans enabling companies to take up this innovation would appear to rapidly benefit the environment, national and international transport.
- **Intervention** to apply this disruptive technology in a conservative industry may be required by governments and influential bodies.

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