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A framework efficiency model for goods transportation, with an application to regional less-than-truckload distribution

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Abstract—A general framework efficiency model for goods transportation is proposed. It is specified for the case of regional less-than-truck load distribution. Quantitative data on the magnitude of the partial efficiencies, their dispersion, and their potential for improvement have been collected from experts in the field using a semi-Delphi procedure. This has identified several aspects of road freight transport which offer major opportunities for efficiency improvement.

Keywords: Efficiency; performance; measurement; transportation; distribution.

1. INTRODUCTION

During the 1990s, interest in the efficiency of logistical operations has increased. The Dutch research project LOPER, for instance [1], tried to assess the efficiency of logistical service firms' operations. The general efficiency of transportation has also been assessed by Tilanus [2].

This paper examines the efficiency of goods transportation. It begins by establishing the theoretical optimum and then analysing the ways in which actual transport systems deviate from this ideal. This involves investigating efficiencies in various dimensions, each of which is broken down into partial efficiencies, until we finally arrive at the actual transport situation. The overall efficiency of this actual situation is then assessed as the continuous product of all the partial efficiencies.

Efficiencies may be assessed *ex post*, and analysed to improve our understanding of the transportation process. If the causal relationships between efficiency and explanatory factors are understood, the potential for improvement can be assessed. A low efficiency may be combined with a high, or a low, potential for improvement; likewise, an already high efficiency may still have a high, or a low, potential for improvement. The objective is to identify those partial efficiencies likely to yield a high potential for improvement.

Efficiencies may also be assessed *ex ante*, and used for planning purposes. If they are used for planning purposes, they must be forecast. Even if the simple average of past efficiency is extrapolated into the future, this is a forecast. Efficiencies can then be considered to be stochastic variables with a mathematical expectation and a variance. In planning a freight transport system, one must take account of variations in the efficiency of different transport operations. Reducing this variability can be an important goal of the improvement programme.

Transport efficiency, as discussed in this article, is only a subset of supply chain efficiency. The supply chain does not only consist of the transformation of place, i.e. transportation, but also of other transformations, e.g. transformation of time (storage) or form (assembly, value added logistics). For these other transformations, useful starting points for overall efficiency measures will have to be developed in the future. This is outside the scope of this article.

Supply chain efficiency, in turn, should be seen in a still wider context of efficiency objectives. Different agencies/organizations will have efficiency objectives which may be in conflict with one another. For example, government may focus on securing reductions in pollution levels or energy consumption, whereas companies may want to make use of transport as a consequence of rationalization of depot locations made possible by improved infrastructure [3].

Even when confining our efficiency objectives to the scope of the individual transportation firm, we realize that measuring physical efficiencies is only one step on the road to a firm's ultimate goal [4, 5]. Research may focus on physical efficiencies other than the ones dealt with in this article, such as transportation lead time [6], or the use of energy [7, 8]. After physical efficiencies, come cost efficiencies. Next to efficiency ('doing things right'), effectiveness ('doing the right things') should be investigated [9, 10]. Customer service and customer satisfaction may be intermediate goals in the pursuit of revenue maximization [11–13]. Total quality management may be the firm's professed objective [14, 15], underpinned a desire to maximise profits. These profits can be maximized in the short, or in the long run. Finally, the firm may supplement the goal of profit maximizing with other objectives such as balancing the interests of the various stakeholders in the business and ultimately ensuring its long term survival.

The structure of this article is as follows. In Section 2, we present the general framework efficiency model for goods transportation. In Section 3, a specific efficiency model is developed for the regional road-based distribution/collection link goods moved over long distances. Expert opinion is presented on the current level of inefficiency, its variability and potential for improvement. The final section presents conclusions and recommendations for further research.

2. A FRAMEWORK EFFICIENCY MODEL FOR GOODS TRANSPORTATION

2.1. Efficiencies

Efficiencies are defined as fractions, or percentages. An efficiency of 100% means that the theoretical, ideal situation is attained. An effiency above 100% means that the theoretical, ideal situation is surpassed. This can only be the case incidentally, for instance if a speed limit is 80 $\mathrm{km\,h^{-1}}$, but the actual driving speed is above that; or if a truck loading capacity is 40 m^3, but actually more is loaded because the driver takes some extra boxes into his cabin.

An efficiency below 100% means that the actual situation falls short of the theoretical, ideal situation. It then depends on the dimension of measurement, whether the actual value should be the numerator and the theoretical, ideal value the denominator, or the other way round. If the dimension measured is 'good', e.g. capacity, time or profit, then the actual value should be the nominator. If the dimension measured is 'bad', e.g. distance or costs, then the actual value should be the denominator.

If the optimum value of the dimension measured is neither the maximum, nor the minimum, but something in between, defining an efficiency measure is more problematic. One can make the actual value the nominator if it is below the optimum value, and the denominator if it is above the optimum. Or else one might drop the dimension altogether and seek an alternative framework in which a maximum or a minimum value is identified as desirable.

An example may be speed. In road transportation, the optimum speed may be the maximum speed allowed by the speed limits on a given kind of road for a given kind of vehicle. But if there are no speed limits, like on the German autobahn, it is difficult to define a speed efficiency. Likewise in shipping, since there are no speed limits imposed on the ocean, we cannot define the maximum speed as the theoretical, ideal situation, but we can define an optimum speed. Here, we could switch to another dimension, like energy or costs, and define an efficiency as minimum energy or minimum costs divided by actual energy used or actual costs incurred. For the time being, we will avoid problems with non-minimum or non-maximum optima, and assume that for each efficiency, the variable concerned should be maximized or minimized.

2.2. General physical efficiencies of goods transportation

The starting point for assessing the efficiency of goods transportation, in any actual, past or future, situation for any mode in any link of the transportation chain, is the theoretical, ideal situation. For goods transportation, this would involve non-stop movement from origin (A) to destination (B), and back, along a minimum distance route, at maximum speed, with a full load. This would represent the theoretical, maximum transportation output.

Overall efficiency (E) in general goods transportation indicates what the actual transportation output is as a percentage of the theoretical, maximum output. Overall efficiency in a general freight context consists of the continuous product of four dimensional efficiencies with respect to time, distance, speed and capacity:

$$E = T \times D \times S \times C. \tag{1}$$

Time efficiency (T) is the percentage of the available time that the vehicle is actually utilized. The ideal situation is literally non-stop, 24-h a day. Many factors, each representing a partial efficiency, detract from this theoretical maximum. For example, the vehicle may only be operated in certain shifts, it may need maintenance and it must stop for loading and unloading.

Distance efficiency (D) is the percentage by which maximum transportation output is reduced by not using the shortest route between origin and destination. Usually the ideal, shortest route will be the minimum, radial distance. Deviation from this route occurs because of factors such as infrastructure, groupage of goods, etc. Distance efficiency is then the radial distance divided by the actual distance.

Speed efficiency (S) is the percentage by which maximum transportation output is reduced by not travelling at maximum speed. We may also consider optimum output in both an economic and environmental sense, taking account of the resource and environmental costs incurred when vehicles move at different speeds. In practice, for many modes of transport and links in the transport chain, the optimum speed is considered to be the maximum allowable speed, defined by technology or legal restriction.

Capacity efficiency (C) refers to the capacity of the vehicle and is measured in terms of either weight or space. It is defined as the percentage by which maximum transportation output is reduced by not travelling at optimum capacity. As with the definition of optimum speed, optimum capacity may be the same as maximum capacity, either in terms of weight or in terms of size of the vehicle, as determined by technology or legal restrictions. For seaships, airplanes, and pipelines, maximum physical capacity is so large as to be difficult to assess.

This description of the general efficiency model for goods transportation may seem quite vague and abstract. It allows, however, for a more concrete specification of each transportation mode or link and provides a framework for identifying and analysing partial efficiencies. This is illustrated in the next section by a case study of a road-based regional less-than-truckload (LTL) and goods distribution/collection operation.

3. REGIONAL BREAK-BULK AND DISTRIBUTION/COLLECTION BY ROAD

The international, or long-distance, transportation chain for LTL goods consists of three links: in one country, or region, the goods are collected in a round trip by a truck; they are grouped into large loads for the long-distance movement by road, rail or water; in the destination country or region loads are disaggregated and re-sorted for final delivery in multiple-drop trips. The delivery vehicle may, in the same round trip, collect goods for transportation from this country, or region, to other countries, or regions. A number of such chains may be integrated into a hub-and-spoke transportation/distribution network [16, 17].

For the purposes of this discussion, we shall confine our attention to distribution/collection operations at a regional level, comprising road trips normally completed within a day, moving to or from a single depot. The number of deliveries per day would be between fifteen and fifty.

3.1. Approach

To help to identify partial efficiencies and assess their stability and improvement potential in this type of freight transport operation, a sample of fifteen experts were interviewed and their views assimilated in what might be called a semi-Delphi process. This took the following form: (1) General efficiencies were disaggregated into partial efficiencies on an *a priori* basis and values assigned to them. (2) The fifteen experts from road haulage and forwarding companies in Sweden and the Netherlands were then interviewed, to obtain their views on the list of partial efficiencies and the proposed weighting system. (3) Their comments were analysed and their quantitative assessments averaged. The results were then returned to the experts and their opinions were sought for a second time, stressing the fact that circumstances and quantitative values in different companies may be different. This was followed up by telephone interviews. (4) After this second iteration, a high degree of consensus was achieved among panel members about both the usefulness of the disaggregation into partial efficiencies and the values that had been assigned to them.

3.2. Partial time efficiencies

The point of departure for time efficiency (T) in regional breakbulk distribution is a road vehicle moving freight non-stop from A to B, and back.

We shall break down time efficiency into four partial efficiencies, called business time (T_b), availability (T_a), utilization (T_u) and driving factor (T_d):

$$T = T_b \times T_a \times T_u \times T_d. \tag{2}$$

Business time efficiency (T_b) is the number of hours per annum that a business operates, divided by 8760 (24-h per day, 365 days per annum). If a professional carrier business is only closed between Saturday 16:00 h and Monday 04:00 h each week the year round, its T_b is 0.79. Business time is mostly constrained by the opening hours at the origins and destinations of freight shipments. Business time efficiency may be significantly improved by night distribution. Experts assessed the actual time efficiency at 0.37 and considered this value to be relatively stable. This figure was fairly stable, but with potential for improvement, by, for example, undertaking more distribution during the night.

Availability (T_a) is the percentage of business time that the vehicle is available for use. An optimum balance should be struck between preventive and corrective maintenance. Breakdowns should be avoided. Repairs, either in one's own workshop or in an outside workshop, should not be delayed by a lack of spare parts. This efficiency is generally well managed. Variability is often due to external factors which are difficult to control. Average panel assessment of this variable was 0.94.

Utilization (T_u) is the percentage of time available that the vehicle is actually used. Non-use may result from lack of business. It is the commercial department's job to achieve a high utilization, while maintaining a reasonable level of flexibility. Business managers often calculate unit costs on the basis of a 'normal' degree of utilization of 0.80. Because our definition is slightly different, time used divided by time available, T_u is put at 0.91. This is a fluctuating efficiency, depending on business circumstances. Commercial departments have quite a number of possibilities to increase the average and reduce the fluctuations.

The driving factor (T_d) is the percentage of operating time spent on the road actually transporting goods. Losses of driving time are due to stops for: (a) resting time for the driver prescribed by law; (b) extra unnecessary stops by the driver; (c) loading/unloading time at the depot or transshipment point; and (d) loading/unloading time at the addresses visited. Loading/unloading time here is a euphemism for the total time that a call takes, which may consist of long waiting times, administrative delays, etc. The smaller the consignment sizes, the greater the number of addresses to be visited, the larger the total stop time and the lower the driving factor. In the distribution of small packages, stop times of over 50% occur. In a typical breakbulk distribution operation, total stop time may be 30%; in other words, the driving factor will be 70%. The experts' assessment was 50%. The driving factor is of major concern of transportation management. It is not only low on average, its fluctuations are a cause of disruption to the distribution process. This aspect of transportation management is sometimes called 'stop management'.

For the numerical assessment given here, time efficiency would be

$$T = 0.37 \times 0.94 \times 0.91 \times 0.50 = 0.16.$$

The greatest scope for improving the average time efficiency would be management of business time and driving time.

3.3. Partial distance efficiencies

The point of departure for distance efficiency (D) is radial distance between A and B. We shall break down distance efficiency into five partial efficiencies, called infrastructure factor (D_i), backhaul factor (D_b), routing factor (D_r), detour factor (D_d), and actual trip execution efficiency (D_a):

$$D = D_i \times D_b \times D_r \times D_d \times D_a. \tag{3}$$

The infrastructure factor (D_i) is radial distance between origin (A) and destination (B) divided by the shortest route from A to B over the road network. The inverse of this factor is sometimes used as a correction factor to derive actual distances over the road network from radial distances in models where radial distances are used. We have seen correction factors between 1.1 and 1.7 in empirical work. The infrastructure factor was assessed at 0.83. Potential for improvement is of course zero from the viewpoint of the individual firm.

One haulier computed the infrastructure factor for his situation as follows. With his vehicle planning package, he planned twenty-seven normal trips along the given road network. The total number of kilometers was 7880. When the same trips were planned using radial distances, the total number of kilometers was 5977. Hence the infrastructure factor was 0.76.

The backhaul factor (D_b) indicates the loss of efficiency due to the fact that there is not always a return load. It is defined as 50% plus half the percentage of trips where there is return freight. In regional LTL distribution, the backhaul factor depends on the percentage of trips where, after distribution or in between deliveries, goods are collected and brought back to the depot or trans-shipment point. If there is a backhaul, the return trip is treated in the same way as the forward haul. Since collected goods often have characteristics different from distributed goods (e.g. fewer addresses and larger quantities) this may introduce inaccuracy into the model [18]. If this inaccuracy is too severe, the backhaul factor should be integrated with the detour factor, to be discussed below. The backhaul factor in regional distribution of LTL freight is assessed at 0.63, with considerable potential for improvement.

The routing factor (D_r) is the inefficiency caused by not visiting the given destinations in the optimal sequence. It is the optimal length of the route via all the delivery points divided by the actual planned route length. The use of vehicle scheduling software packages is helping firms to route their vehicles more efficiently.

However, the route to be taken via a given number of addresses may be longer than the exact travelling salesman solution for other, more serious reasons than suboptimal heuristics: certain vehicles and even drivers may not be allowed to visit certain addresses; and, most seriously, certain addresses may not be visited at certain times. The trouble is that in practice shippers are demanding deliveries within narrower time windows and increasingly at the same time. Also in urban distribution, the municipal authorities are imposing tighter restrictions on delivery times.

One haulier computed the cost of time windows as follows. In his situation, 17% of all shipments had time windows imposed on them. Except for the time windows, there was no reason to suppose that these shipments differed from the other shipments. Sample trips were planned with and without time window restrictions. In the latter case, transport costs were 18% lower. Time window restrictions were found to double the distribution costs for the shipments concerned. The routing factor is assessed at 0.85 and is considered to offer potential for improvement.

The detour factor (D_d) is the straightforward consequence of the fact that shipments are grouped and delivered in round trips rather than in full truckloads transported directly between the depot and the first address, between the depot and the second address, etc. Even if the routing factor is 100%, i.e. if the sequence in which the addresses are visited is optimal, the detour factor may be well below 100%. D_d is defined as the single distance between the depot and destination i multiplied by the size of shipment i, summed over all shipments i, divided by half the total length of the roundtrip multiplied by vehicle capacity. Since the return trips are already dealt with by the backhaul factor, here we only deal with the forward trips, considering half the distance of the roundtrips to be forward trips.

The detour factor is inherent in LTL distribution, but it seriously reduces efficiency. Given the trend of decreasing shipment sizes, the detour factor is getting more serious and there is not much that can be done about it, except for the hauliers to calculate the detour factor into their freight rates and let the shippers decide if they wish to send freight in smaller consignments. Expert opinion assesses the detour factor to be 0.62, and offering some scope for improvement.

For an example, consider Fig. 1. From inspection, it can be seen that the optimal route is A–B–C–D–E–A of length nineteen units. If a vehicle instead takes the

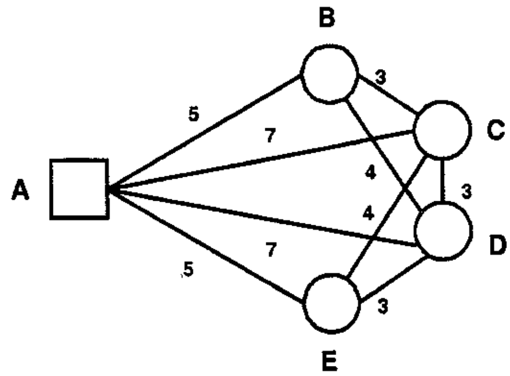

Figure 1. Numerical example of road network, to explain routing factor and detour factor.

actual route A–B–D–C–E–A, the length of the trip is twenty-one units. The routing factor is therefore 19/21 or 90%. Now consider a truck departing from A and delivering one quarter truckload at B, C, D, and E each. If the truck makes this trip, along the optimal route, four times, and covers a length of $4 \times 19 = 76$ units, it has delivered one full-truck-load (FTL) at each address. Alternatively, the truck might deliver one FTL by four return trips to B, C, D, and E, each covering fourty-eight units. Hence the detour factor is 48/76, or 63%.

One haulier computed a somewhat more realistic example. He planned ten normal trips with twenty stops; the total length was 2696 km. Assuming that all deliveries were equal to 1/20 of a full truckload, each trip would have to be executed twenty times in order to get one FTL at each address, in total, 53 920 km. Alternatively, the total length of 20 FTL trips to each of the 20 addresses was calculated: 40 230 km. Hence the detour factor for this sample was 0.75.

The actual trip execution efficiency factor (D_a) is the ratio of planned trip length to actual trip length. This may be greater than 1, but will usually be below 1, due to unforeseen detours, wrong directions taken, wrong addresses visited, etc. The average trip execution efficiency factor is assessed at 0.88, with quite a large dispersion, and potential for improvement.

For the numerical assessment given here, distance efficiency would be

$$D = 0.83 \times 0.63 \times 0.85 \times 0.62 \times 0.88 = 0.24,$$

with some potential for improvement, especially in the backhaul and trip execution efficiency factors.

3.4. Partial speed efficiencies

The point of departure for speed efficiency (S) is the maximum speed allowed by law for trucks anywhere in the country.

We distinguish two speed efficiencies, called speed limit factor (S_l) and congestion factor (S_c):

$$S = S_l \times S_c. \tag{4}$$

The speed limit factor (S_l) is the actual average speed limit over the roundtrip route divided by the maximum speed allowed in the country. For average speed, the harmonic average must be taken. For example, for one third of a roundtrip route a speed limit of 80 $\mathrm{km\,h^{-1}}$ is allowed, for one third a limit of 60, and for one third a limit of 40; the maximum speed for a truck allowed in the country is 80 $\mathrm{km\,h^{-1}}$. Then the actual average speed limit is 55.4 $\mathrm{km\,h^{-1}}$ and the speed limit factor is 0.69. The speed limit factor is assessed at 0.71 overall and the haulier can do nothing to improve it.

The congestion factor (S_c) is the actual average speed driven over the roundtrip route divided by the average speed limit over the roundtrip route. Assuming that truck drivers generally drive as fast as they can, efficiency losses are mainly due to congestion of the roads, including difficulties in finding a parking space. The congestion factor is assessed at 0.75 and is fast declining as the road system approaches full capacity utilization. Furthermore, the congestion factor is, unlike the speed limit factor, highly unstable, which makes vehicle scheduling, within narrow time windows and just-in-time deliveries, virtually impossible. No individual haulier can do anything about it. Only concerted action by government may help. According to expert assessment, speed efficiency would be

$$S = 0.71 \times 0.75 = 0.53,$$

unstable, with little prospect of improvement.

3.5. Partial capacity efficiencies

Depending on whether weight, or volume is the binding constraint, capacity efficiency (C) should be broken down in a few, or many partial efficiencies. With weight, the series of efficiencies would proceed from maximum gross vehicle weight, via maximum payload weight and various gross packaging weights, to net product weight.

The experts agreed that volume is usually the binding constraint in regional LTL distribution. Capacity efficiency is split into seven partial volume efficiencies: capacity factor (C_c), floor occupancy (C_f), height utilization (C_h), pallet load factor (C_p), box load factor (C_b), net product factor (C_n), and actual loading execution efficiency (C_a):

$$C = C_c \times C_f \times C_h \times C_p \times C_b \times C_n \times C_a. \tag{5}$$

The capacity factor (C_c) is the actual load volume in cubic metres of the vehicle occupied as a percentage of the maximum possible load volume in cubic metres permitted by technology (e.g. short coupling) and law (e.g. minimum cabin length, maximum vehicle length and height and width). An average load volume in regional LTL distribution may be 40 m^3, as opposed to 120 m^3 maximum load volume in the Netherlands, giving a capacity factor of 0.30. An increase in vehicle dimensions would limit access to the delivery addresses, so there may not be much potential for improvement of this factor. Note that in Sweden the maximum load volume is about 170 m^3 for a 24-m, high-volume truck combination. The experts' assessment of the capacity factor is 0.27.

The floor space occupancy factor (C_f) defines the percentage of the floor space occupied by freight, say, pallets. If pallet loads are protruding, pallets may not fit neatly into the available truck floor area. Floor space may also be lost due to odd-shaped cargo units like machines, carpets, etc. The C_f of a fully laden truck is assessed at 0.83, with some room for improvement.

The height utilization factor (C_h) is the average proportion of the available loading height in the vehicle that can be occupied by the freight. If two pallets of 15 cm thickness are stacked on top of each other with 9 cm manoeuvering space above them, gross height of, say, 3 m, is already reduced by 39 cm, giving a C_h of 0.87. If the pallets were replaced by slipsheets, efficiency would improve by a greater margin than could be achieved by raising the routing factor. On average, C_h is assessed to be very low, *viz.* 0.47, and variable, and it is deemed worthwhile to investigate possibilities of improvement, for instance, by installing a double deck.

Hauliers and forwarders are less interested in the following volume-related efficiencies. In theory they should be of greater interest to the shippers, though as the freight rates that they pay relate more to the weight carried, minimizing the volume of consignments is seldom a priority.

The pallet load factor (C_p) is the sum of the volumes of the boxes loaded onto the pallet as a percentage of the imaginary enveloping box around the pallet load, consisting of its floor area multiplied by its net height (excluding the height of the pallet itself, which is accounted for in the height utilization factor). It is one minus the percentage of 'air' within the enveloping box. It is assessed as averaging 0.69, being quite variable and offering potential for improvement [19].

The box load factor (C_b) relates to the internal capacity of the boxes on the pallet. It is the percentage of the total cubic capacity of the boxes that is occupied by, let us assume, the final, smallest packaging unit, probably the packaging unit that is sold in the shop. Usually, sales units fit well into their boxes. Hence, C_b is assessed at 0.88, stable and with hardly any potential for improvement.

The net product factor (C_n) is the percentage of the space in the final packaging unit occupied by the actual product. This percentage may be quite small. For instance, the volume of pure perfume as a percentage of the retail package size may be around 10%. From a marketing standpoint, it is often desirable to distribute products packaged in larger and more elaborate containers as this can increase sales. The average C_n is assessed at 0.39, a variable figure, which for commercial reasons, would be difficult to improve.

The actual loading execution efficiency (C_a), finally, is a residual efficiency to take account of all volume efficiency losses that have not been accounted for elsewhere and that may be caused by the fact that actual stowage is not according to plan. It is assessed as being variable, with an average value of 0.86 and worthy of further investigation by operations managers.

The capacity efficiency resulting from the numerical assessment reported here would be:

$$C = 0.27 \times 0.83 \times 0.47 \times 0.69 \times 0.88 \times 0.39 \times 0.86 = 0.021.$$

3.6. Summary of the expert assessments

Table 1 summarizes information collected from the experts. Multiplying the partial efficiency indices for the four dimensions yields the following estimate of overall efficiency for regional LTL distribution (Eqns (1)–(5)):

$$E = 0.16 \times 0.24 \times 0.53 \times 0.021 = 0.00043.$$

The fact that this is less than one thousandth may be a surprising result, but it should be remembered that the theoretical, ideal starting point was an extreme position, far removed from the real world situation. It is more important to consider possible improvements. If efficiency is increased to one thousandth, for example, it is more than doubled!

Table 1.
Expert consensus, with a cut-off after two rounds, for the case of regional LTL distribution by road

Partial efficiency	Expert assessments		
	Average (percentage)	Dispersion[a]	Potential[b]
T_b (business)	37	1.2	3.2
T_a (availability)	94	2.8	1.1
T_u (utilization)	91	2.4	2.2
T_d (driving)	50	3.3	3.5
D_i (infrastructure)	83	1.0	1.0
D_b (backhaul)	63	2.6	3.4
D_r (routing)	85	1.6	2.2
D_d (detour)	62	1.4	1.9
D_a (actual)	88	2.7	2.6
S_l (limit)	71	1.0	1.0
S_c (congestion)	75	3.6	1.0
C_c (capacity)	27	2.2	1.5
C_f (floor space)	83	2.7	2.6
C_h (height)	47	4.1	3.1
C_p (pallet)	69	2.2	1.8
C_b (box)	88	1.3	1.2
C_n (net product)	39	2.5	1.0
C_a (actual)	86	3.2	2.8

[a]Coefficient of variation on a five point scale; 1 = very small, 5 = very large.
[b]Potential for improvement on a five point scale; 1 = very little, 5 = very much.

4. CONCLUSIONS

A general, four-dimensional, physical efficiency model of goods transportation has been formulated expressed in the dimensions of time, distance, speed, and capacity. The overall physical efficiency measure of goods transportation is the continuous product of the four dimensional efficiencies.

The model has been applied to the case of regional LTL distribution/collection by truck. We have broken down the four dimensional efficiencies into eighteen partial efficiencies. Our starting point was an unattainable, theoretical, ideal situation in which goods are transported continuously, non-stop, along the shortest route, at maximum speed, at maximum vehicle capacity, from A to B and back.

The reason for studying this long trajectory is for managers and researchers not to overlook any possible avoidable loss of efficiency and not to focus prematurely and exclusively on certain well-known, partial problems, like the vehicle routing problem. The suggestion is that sometimes more efficiency can be gained from simple measures than from complicated and sophisticated ones.

The usefulness of the breakdown into the partial efficiencies was evaluated and their numerical values were assessed empirically using a semi-Delphi method in two rounds, involving fifteen experts from eleven road haulage and forwarding companies in Sweden and the Netherlands. The experts assessed the average efficiencies, their dispersion, and their potential for improvement.

The overall efficiency, calculated as the continuous product of the assessed partial efficiencies, was 0.00043. This is no reason for despair, however, because the starting point was a theoretical construct and should be regarded simply as a base-line against which improvements can be measured.

The results of this study show that a theoretical starting point for an overall physical efficiency model of goods transportation can be found based on a full range of partial efficiencies.

The empirical results have identified several aspects of regional LTL distribution/collection as having a low average efficiency and/or a high coefficient of variation, combined with a good potential for improvement (see Table 1); in particular: business time (T_b), driving time (T_d), backhaul factor (D_b), actual trip execution (D_a), floor space utilization (C_f), height utilization (C_h), and actual loading execution (C_a).

It is the authors' intention to study a number of partial efficiencies in depth. A promising area of further research seems to be stop management—the control of the stopping times of distribution vehicles (the stopping factor being one minus the driving factor). The impact of high-quality information systems (vehicle navigation systems, on-board automatic registration systems, mobile communications systems and the like) and their impact on the various partial efficiencies (driving factor, backhaul factor, routing factor, detour factor, trip execution factor and the like) are also proposed for further research.

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