A New Paradigm for a Sustainable Automotive Industry

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Abstract

The paper considers the current difficulties faced by the global automotive industry and why the 20th century model on which it is based needs to change. A novel and innovative concept for a **Fixed Life Car (FLC)** is proposed to be implemented through **EU** legislation. This, it is suggested, will close the existing open loop vehicle system and produce the conditions needed for a sustainable automotive industry to be created. Analysis is provided by a **THREE YEAR FLC** which at the end of vehicle life (**ELV**) is then remanufactured and sold under full warranty as a new class two car. The process is repeated and after nine years the vehicle is scrapped. This policy is shown to triple the output of vehicle production and provide significant benefits to customers and legislators. At **ELV** design for disassembly techniques developed for the **FLC** is shown to provide recovery of residual value from metalformed components by selling them for reuse as preforms for other applications. Significant reduction in energy and CO_2 are identified from savings of new raw materials. Examples are also given to show that in certain circumstances vehicle manufacturers could obtain full recovery of component costs producing 100% sustainability.

1 Introduction

In 2007, before the global automotive industry fell off a cliff, **75 million** vehicles were produced which with the aftermarket was worth **~2.7 x 10^{12} Euro** (**~4% of world GDP**) /1/. This represented **~17%** of all manufactured goods, employed **~5%** of the world total manufacturing workforce and used **~15%** of the world output of steel /2/, /3/, /4/.
At the time of writing this paper (February 2009), no one in the global automotive sector has any idea of how far or how quickly the industry production and sales figures may fall or indeed how long they may take to recover. At the end of January 2009, Carlos Ghosn was predicting a **20%** fall in the global passenger vehicle market for this year and

Goldman Sachs were forecasting that the car market in Western Europe would also drop by **~20%** to **~10.7** million vehicles /5/, /6/.

In 2007, there were just over **20 million** vehicles produced in the **EU** in **102** assembly plants /7/. Of these, **13 million (65%)** were passenger cars. A study of the average output and capacities from **16** vehicle manufacturers operating in **EU** countries showed average assembly plant utilisation at **~86.8%** with a standard deviation of **11.7**. The maximum utilisation was **105.7%** and the lowest **58.6%**. Since the production output figure for breakeven is generally agreed to be **80%** of full capacity, it shows 2007 was a good year for the automotive industry in Europe. However, in 2009 with market sales plummeting, in some areas by over **60%**, radical actions are clearly required.

It is perfectly possible that before this paper is presented some of the automotive industry leading global companies, both vehicle makers and their supply chain partners, will be in **receivership**. If this happens, their empires will be broken up and absorbed by the companies which survive, perhaps with newer players entering the global scene. What is certain, is that the **20th** century mentality of unfettered growth at all costs and the paranoid demand for greater market share, again, almost at any cost, cannot be permitted to be the model for automotive manufacture in the **21st** century.

Amongst the current uncertainty and gloomy prospects for tomorrow one fact is undeniable. Some time in the future, the 2007 demand for automotive vehicles will be exceeded. This is because the growing global expectation for individual freedom of travel is virtually insatiable. For example, the USA has the highest density of vehicles in the world at **~800 per 1000** head of population. In China the figure is **9 vehicles per 1000** people /8/. It has been calculated that if China were to have **100 vehicles per 1000** population (eight times lower than in the USA) its home market demand would be in the region of **42 million** vehicles per year. This, of course, is the primary reason why the global players believe they must be part of the Chinese automotive market. Forecasts have shown that by 2030 China will have around **one fifth** of the **global vehicle parc of 2 x 10^9** but still with **269 vehicles per 1000 people** /9/. Automotive saturation in China, whenever it occurs, has been calculated to be around the USA figure of **four** vehicles for every **five** people. Given this almost unimaginable manufacturing scenario, the question which this paper seeks to address is, **"What sort of sustainable automotive industry can the world afford to support in the 21st century and how can this be achieved?"**

In the short term the very natural concern is survival. Hence the various current national financial **'bailouts'** to provide the credit required for auto makers and their suppliers to remain technically solvent and in business. However, having money in the bank does not sell vehicles and in the short term the automotive industry needs to sell vehicles. Over recent years a number of European governments have offered tax incentives and cash back payments to motorists who have scrapped old cars and bought new ones. This naturally reduces the pollution from less efficient engines (CO_2 from a new European car is **30 times** lower than from the average global car) and has provided some vehicle manufacturers with a boost in sales. To date, this has only happened sporadically amongst countries within the **EU** and has largely been of little concern because overall, the market across Europe was buoyant enough to absorb it. However, in the present economic circumstances and to counter any perceived threat of protectionism, moves are currently being made to establish a **EU** wide old car scrapping policy /10/. This, it is claimed, could be one way to get the market moving again and to sell the tens of thousands of vehicles currently piled up at docks, on disused airfields and on almost any available flat land. At the other end of the supply chain, orders for new components have reduced to levels which cannot be considered viable. Hence the urgent need to create a new paradigm for a sustainable automotive industry.

2 The 20th Century Automotive Industrial Model

Many substantial and profound problems exist within the current automotive industry. This is perhaps not a surprise since its development over **100 years** has taken place largely by happenstance. More recently, because of the increased number of vehicle segments (**now over 40**) and the inevitable reduction in the number of high volume models produced, **build to order** became the sensible goal for manufacturers to aim for. Hence, the global effort to obtain cost effective flexible production. Laudable though these endeavours have been, they, like almost every other aspect of the automotive industry, can never achieve a balanced state because they operate as part of an **open loop system**.

To explain, a vehicle manufacturer produces a car. It does not matter if it is **build to order** or produced as stock to keep production running. In either case the vehicle is sold and as far as the maker is concerned they never want to see it again – particularly under a warranty chain. Eventually, at **ELV**, which in the UK would be an average **13.2 years**, the vehicle is returned to the manufacturer to dispose of at no cost to the owner. Because at **ELV**, the value of material in the car is less than **1%** of when it was new, scrappage is seen by the manufacturer as being an **indirect tax** on the business.

Once a new vehicle is sold the manufacturer has no further interest in it, servicing being delegated to dealerships and the aftermarket given over to those suppliers specialising in that end of the market. In short, there is a **total disconnect** between what goes into the market as a new vehicle and what comes out as scrap. After the warranty period has expired, to coin a phrase, the vehicle manufacturer, could not ‘give a damn!’ what happens to the car. However, if the life of a vehicle were to be **fixed by legislation** there would be no old, inefficient or inherently unsafe cars on the roads and the demand for new vehicles would be significantly easier to predict.

3 A Fixed Life Car (FLC)

Legislation to determine the period of time over which a car may be used is the key to a **sustainable automotive industry**. This would require all passenger vehicles to be returned to the original vehicle manufacturer at a fixed time after the date of first registration /12/. To illustrate the model, the fixed term suggested in this work has been chosen as **THREE YEARS**. At this time of trade-in, a **fair depreciation** is paid to the vehicle owner who then buys a new car. In the **UK**, the existence of an annual Motor Vehicle Test (**MOT**) for vehicles over **3 years** old, encourages those who find it practicable, to exchange their vehicles within this time period. Having had the vehicle returned after **3 years** of use, the original manufacturer would then **fully remanufacture** it and offer it for resale as a **‘new’ class two car** with full warranty etc., and at a lower price than when it was first sold.

At the end of a **second 3 year period**, the owner of the vehicle returns it to the manufacturer and a fair depreciation is paid. Once again, the vehicle is remanufactured and offered for sale as a **‘new’ class three car** with full warranty this time at a lower price than the previous sale.

After a **third, 3 year period**, the vehicle is once more returned to the manufacturer and this time it is **scrapped**. **Fig. 1.** shows how a three year system could operate, illustrating that from **year 4**, vehicle manufacturers would **double** their current output of vehicles and from **year 7** this would be **tripled**.

	New Vehicle Class (10^6)			**Existing Cars (10^6)**		**Total Cars (10^6)**
Year	1	2	3			
1	15	0	0	15	15	45

2	15	0	0	15	15	45
3	15	0	0	15	15	45
4	15	15	0	0	15	45
5	15	15	0	0	15	45
6	15	15	0	0	15	45
7	15	15	15	0	0	45
8	15	15	15	0	0	45
9	15	15	15	0	0	45
10	15	15	15	→ Scrap 15		45
11	15	15	15	15		45

Fig. 1. Introduction of Three Year Car Programme. Assumption ~15 million Class One passenger vehicles produced/year

Fig. 2. gives an outline of elements which might be included in a **vehicle remanufacturing line**. As can be seen, this includes a major involvement for the upstream supply chain, which through development of **modular designs** could be implemented by the **exchange of the assembled elements**. It also shows the direct line side involvement of the automotive Tier One supply chain and their support within the new paradigm.

All vehicles of modular construction			
Operations		**Activities**	Involvement
Strip down	1.	Remove all loose items (spare wheels etc.)	Tier 1
	2.	Steam clean and dry	VM
	3.	Palletise	VM
	4.	Remove wheels and closures	Tier 1
	5.	Remove interior elements	Tier 1
	6.	Remove engine and gearbox	VM
	7.	Remove suspension	Tier 1
	8.	Remove steering	Tier 1
	9.	Remove fuel lines	Tier 1
	10.	Inspect bodywork	VM
Rebuild	11.	Facelift body	VM

	12.	Replace fuel lines	Tier 1
	13.	Replace steering	Tier 1
	14.	Replace suspension	Tier 1
	15.	Replace engine and gearbox	VM
	16.	Replace interior	Tier 1
	17.	Replace wheels and closures	Tier 1
	18.	Inspect and test	VM
	19.	Drive out	VM

Fig. 2. Idealised remanufacture of Class Two & Three Cars

At the **end of life vehicle (ELV)**, disassembly techniques incorporated in the vehicle design will allow many of the metallic components to be stripped out and sold on as preforms for alternative use. Since every metal part on a vehicle has full provenance throughout its original manufacture and subsequent use, it can be stripped down, cleaned and offered for sale in **a new web based business venture**. The savings for the purchaser of such parts would be in obtaining a near to final shape product available for immediate dispatch at an attractive price compared with new material stock saving both the **energy of crude steel** manufacture and its associated **CO_2**.

4 Implications of a Fixed Life Car Programme

4.1 Vehicle Supply Chain

Fig. 3. shows the up and down stream supply chain involvement required to bring about a **Fixed Life Car (FLC)** within the **EU**.

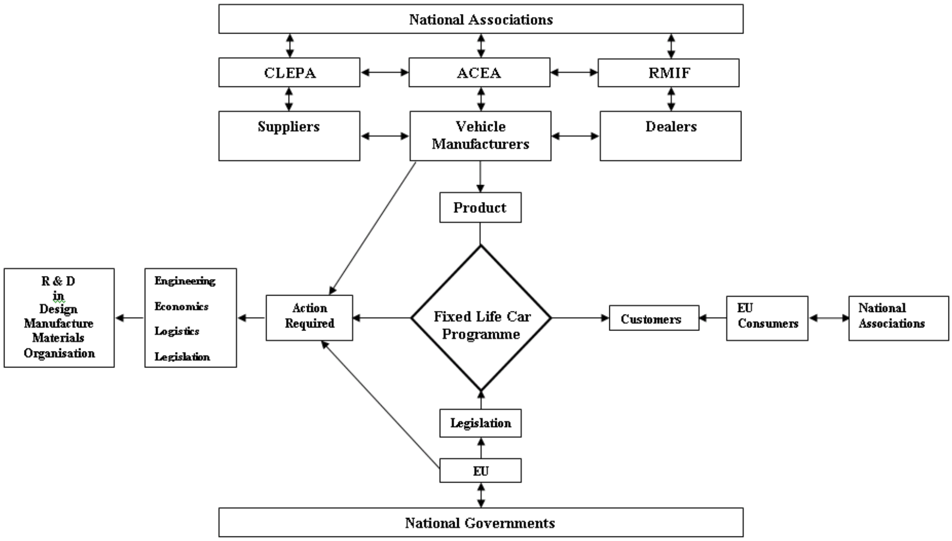

Fig. 3. Diagram showing participants and requirements for a European Three Year Car Programme

As happens now, suppliers of components would produce and provide exactly the same number of parts to make the initial vehicles which the market demands. However, because the definition of Remanufacturing requires a product to be made at least as well as a **'new' one with full warranty** etc., it follows that the original part suppliers would be responsible for the remanufacture of their own products. To be successful, remanufacturing a vehicle would require significant redesign to allow for **ease of disassembly**. This new and innovative technological ability could be developed in the **EU** through the introduction of education and training grants across the supply chain. In short, it would provide automotive engineers with a blank sheet of paper opportunity to create an innovative **design for disassembly discipline** allowing the creation of entirely new products.

On the downstream side of vehicle manufacture, automotive dealers and marketing people would have the opportunity to sell **three times as many new vehicles** as they do now. Of particular importance would be the direct linkage they would maintain with the vehicle owner and the chance to establish customer loyalty through a series of sequential purchases and special offer deals.

In addition, **original equipment manufacturers (OEMs)** would have the ability to introduce regular model changes and with them, uprated features to incorporate technical improvements of efficiency, performance, safety and comfort. These would ensure the **OEM's** competitiveness in the market.

Although globalisation lies at the heart of all manufacturing, **FLC** legislation would require any car imported into the **EU** to be exported again after three years unless the vehicle manufacturer established a manufacturing facility to remanufacture it. This would introduce a level of **localisation** into an increasingly globalised manufacturing environment.

4.2 Legislators/Regulators

For those involved with ensuring **EU** governance, the introduction of a **FLC** would achieve a safer, environmentally friendly and sustainable **EU** automotive industry. In addition to the above benefits, it would also be possible to provide continuous updating/uprating of **vehicle sensory systems** within each three year remanufacturing period to facilitate the **control and monitoring of traffic movements**.

4.3 Consumer/Customer

The benefit to customers would be a lifetime guarantee on all parts and labour – in effect, **trouble free motoring**. All cars being new would be safe, efficient and environmentally friendly, virtually eliminating the scourge of dangerously repaired vehicles and theft. As a future possible target, **OEM's** could seek to provide vehicles for the domestic user which required no servicing over their **3 year** life and hence would incur no garage charges!

5 The Opportunities at ELV

The current average materials used in a passenger vehicle include **~75%** of metallic components. These breakdown into **~67%** ferrous, **~6%** aluminium and **~2%** other materials /12/. Considering only forgings, in 2007 **~1.5 million tonnes** of forged parts were produced in Europe for use in passenger cars /13/. Current **ELV** regulations require vehicle manufacturers to recycle/reuse at least **85%** of the scrapped materials and to limit landfill. Vehicle manufacturers meet this challenge through partnerships with **salvage/dismantlers** where most metallic materials are shredded for remelting. In consequence, the vehicle manufacturer recovers **~1%** of the value of the original metal products. However, if components were designed to be as easy to disassemble as to assemble and if they only had three years of effective use between remanufacture, then it is perfectly practicable to establish an entirely new business in marketing the metallic components as **near to shape preforms** for reuse in other engineering applications e.g. lawn mowers, white goods etc.. Every component on a vehicle has a full audited provenance and at **ELV** would also have a full description of its previous use within the vehicle e.g. number of kilometres travelled etc.. As will be shown, if sold as a preform, its value would be over **25 times greater** than that which could be obtained were it to be remelted as scrap.

To realise such a business opportunity would be quite straight forward and could be developed and run on behalf of a vehicle manufacturer by their steel supplier(s), To illustrate, all vehicle components have a **CAD file** which contains every detail of design, material, manufacture etc.. At Nottingham we have been developing software which can **identify features from a STEP file**. These component features can then be posted on a website together with the rest of the product information. Before purchasing new material stock, any potential customer could visit the website and quickly search for sample parts close to what is required. If found, orders could be placed and parts despatched almost by return. The saving to the customer would be a material which, being close to the shape required, could significantly reduce the cost of manufacture and the **energy** and **CO_2** involved.

Taking the Euroforge figures of **1.5 million tonnes** of automotive forgings produced in 2007 for passenger cars and LCVs. At **€900/tonne**, this material would cost **€1.35 x 10^9**.

Assuming the material cost was **50%** of a hot forging, then the value of **1.5 million tonnes** of hot forgings would be **~€2.7 x 10^9**.

Assuming the hot forgings to be **25%** of the price of the finished machined components, then the value of the forged parts would be **~€1.1 x 10^{10}**.

Assuming that at **ELV**, **33%** of the original **1.5 million tonnes** was to be remelted at a scrap value of **€200/tonne**, then the **return on investment (ROI)** for the vehicle manufacturer would be **€100 million** i.e. **~7%** of the initial material cost.

Selling preforms at say, **25%** of their finished part value **(€1.1 x 10^{10})** would provide a return to the **OEM** of **~€~2.75 x 10^9** i.e. ~ **27 times** the value which could be obtained from remelting.

In an industry intensely obsessive about **'lean' manufacture**, it is surprising that in reality, 'lean' at **ELV** means **low cost destruction**. That a vehicle manufacturer chooses to destroy what they own with little attempt to recover and release some of its locked in value is, frankly astounding. Enormous effort has been put into assessing the depreciation of lease vehicles to obtain a precise measure of their **residual resale value**. These existing leasing data would be the financial driver for a **FLC**.

However, in the case of a **FLC**, at **ELV**, many of the metallic components will have residual values to non automotive purchasers perhaps equal to or greater than the original cost of manufacture. This is because in the decade since the components were first manufactured, the cost of raw material is likely to have increased. Secondly, those wishing to purchase limited numbers of goods would be obliged to pay a premium price for small quantities of raw materials relative to the much lower price paid by the automotive manufacturers. Finally, the automotive manufacturers pay prices for their vehicle components based on **scale of economy** which means their piece part price will be a fraction of that paid by a small or medium scale purchaser of similar parts.

Hence, it is not at all inconceivable that if a vehicle manufacturer introduced the concepts of 'lean' into **ELV** they could perhaps obtain a **full recovery of cost** on their parts by selling the materials as preforms for other applications thus achieving **100% sustainability**.

Taking the 2007, **1.5 million tonnes** of forged parts as an example, the implications of such a **'lean' recovery system** would be significant. Clearly, this could not be the case for all materials and components throughout the vehicle but it might introduce a **new design goal** for **OEM's** to seek to maximise the residual value of their parts at **ELV**.

For example, if **50%** of the forgings made in **2007** were sold on as preforms, it would save the manufacture of **0.75 million tonnes of crude steel**. This would save **~1.5 x 10^7 GJ of energy** and **1.3 million tonnes** of **CO_2** at 2008 values. In addition, because the geometry of a preform would be near to net shape, this would also save the **energy of manufacture, CO_2 etc.** for shaping from new stock, plus the **energy/CO_2**, required for recycling the swarf, cutting fluids etc etc.. In short, rationalising their assets at **ELV** could release significant locked in residual value back to the vehicle manufacturers. They could then see a closed loop system where development of 'lean' recovery systems within the design for disassembly methods could provide the stimulus for significant longer term rewards and payback.

It is appreciated that some vehicle manufacturer's in-house component manufacturing costs are often configured to ensure that outside sources cannot compete. In the same way, outsourced suppliers are themselves knowledgeable enough to make sure they are able to provide both price down and profit from within the bidding system. Notwithstanding that these well practiced situations exist, it is reasonable to assume the following:

1. that global vehicle manufacturers can purchase their ferrous materials at **50%** of the price a small and medium enterprise (**SME**) would have to pay a stockholder
2. that over a **10 year** period steel prices would increase by **50%**
3. that economy of scale would mean a vehicle manufacturer could obtain finished components at **25%** of that which an **SME** would have to pay
4. that over a **10 year** period the costs of manufacture would increase by **50%**

Given this scenario, consider the cost of a **1kg** unmachined hot forging purchased at a cost of **2*x*** (where ***x*** is the cost of material). The rough forging is then machined and heat treated increasing the piece part cost to **8*x***.

At the **ELV (10 years)**, the original material price has risen to **1.5*x*** and if the material to forging ratio is the same as **10 years** earlier would mean the forging was **now 3*x***. In **10 years**, the manufacturing costs of **6*x*** will have increased to **9*x***. Therefore, the value of the component relative to its original cost of manufacture is now **12*x*** and not the **8*x*** originally paid i.e. a **33%** cost increase.

Consider now an **SME** wanting to manufacture a component similar to that which could be obtained from an **ELV**. The **1kg** piece of raw material would cost the **SME 2*x* times 1.5** →**3*x***. The manufacturing costs would be **9*x* times 4 (scale of economy factor) → 36*x***.

This would mean the cost of manufacturing the part for an **SME** would be **39*x***. Now, if the vehicle manufacturer sells the component as a preform to an **SME** at a price of **8*x*** this would cover the original cost to the vehicle manufacturer and mean that over a decade of use, the part had **cost nothing!** An **SME** would obtain a near to shape component at **~2.7 times** more than the **3*x*** cost of new material. However, this would require less work to finish than would new raw material. Assuming the vehicle manufacturer's cost ratio of **2*x* : 6*x*** for a forging to finished part were extended to the **SME**, the finishing cost for him would change from **8*x* to 24*x***. The total **SME** cost would then be **32*x*** yielding **~18% saving** relative to making the component from new stock. This does not include any energy savings obtained by using a preform through reduced machining, waste disposal etc.. Also, by selecting a preforming route, the piece parts could be ordered and delivered on site within a matter of hours. Of course, by introducing a 'lean' culture to this new design philosophy for achieving enhanced value at **ELV**, a resourceful vehicle manufacturer could maximise the **ROI** by introducing into the vehicle design, a range of standard part geometries which would increase the future opportunities for the resale of preforms to a third party.

A more advantageous step however for a ‘smart’ vehicle manufacturer, would be to design the various parts so that after suitable ‘restorative’ heat treatments they could be **reused in-house** or through the supply chain to produce the **next generation of vehicles**. This would double the life of the material and, as shown in **Fig. 4.**, provide a **25%** cost saving compared with the use of new material. For every tonne of reused parts, the **savings in energy and CO_2** at 2008 levels would be **20.6 GJ** and **1.7 respectively**. Given the clear environmental and commercial benefits for **FLC manufacturing and material reuse**, it would appear self evident that taxpayer support could provide significant advantages not only to obtain improved quality of life for **EU** residents but also by producing new business opportunities and employment to sustain living standards.

	Cost of component manufacture (in terms of *x*)				**Energy CO_2 savings**	**Cost Savings**
Component Manufacturer	Material	Hot Forging	Machining and finishing	Total	20.6 GJ/tonne/1.7 tonne/tonne	In terms of *x*
OEM using new material	*x*	2*x*	6*x*	8*x*	No	
Increase in costs after 10 years	1.5*x*	(3*x*)	1.5*x* (9*x*)	(12*x*) (12*x*)	No	
SME vs OEM using new material	3x 3 : 1		36*x* 4 : 1	39*x* ~4.9 : 1	No	
SME reusing ELV preform		8*x*	24*x*	32*x*	Yes	~18%
OEM reusing ELV preform			9*x*		Yes	~25%

Fig. 4. Comparison of costs associated with the manufacture of an automotive hot forged component by an OEM and SME using new and reused material

6 Progress Towards a FLC

Perhaps the first point to make about a **FLC** policy is that it could have notable exceptions. For example, **'classic cars'** could permitted to be used but as their age and rarity increases along with their value they will have a diminishing importance to daily motoring.

Those purchasing and running **'super cars'** are unlikely to see any major impact on their lifestyle or pockets given the existing costs of depreciation, servicing, and insurance against the distance travelled per year will already be exceedingly high. The main impact will be the takeover of the current used car market by the vehicle manufacturers and of the aftermarket in those regions where a **FLC** policy is adopted. Since the aftermarket currently generates the same income as does the market for new vehicles this would be **~€1.0 x 10^{12}**. It should also be noted that a **FLC** policy will also eliminate the market for counterfeit parts adding to economic stability for suppliers and safer vehicles for users.

In essence, a **FLC** policy would offer a system around which every aspect of the automotive industry can be **reviewed**, **reconsidered** and **replanned** allowing new ideas for business opportunities and social benefits to be developed and established. To achieve these objectives would require the various stakeholders shown in **Fig. 3.** to link up to form networks. The groups would deal with matters as diverse as: supply chain logistics, crime prevention and safety through to green transport and manufacturing sustainability, meeting to plan how the various elements made possible by a **FLC** could be brought together and made to work.

It is envisaged that the initial legislation would be passed by the **EU** Parliament and rolled out across the member states. As with most **EU** legislation, the detailed operational factors would be left to the various national legislative bodies to determine and introduce. This would mean that the regulatory bodies for road transport in each **EU** country could administer its policies on whichever way is considered most appropriate to meet the central **EU Directive**. It is considered this process would be on-going with perhaps full **FLC** implementation being possible by Q2 of the century.

If a **FLC** policy is adopted in the **EU** countries and is shown to offer the benefits outlined above, it is inconceivable that similar schemes would not be adopted in both **NAFTA** and

China as major regional zones. In terms of passenger car production and sales that would be the major part of the global market.

7 Conclusions

The Fixed Life Car (**FLC**) has introduced an innovative and radical concept which would close the loop in a vehicle life. For a **FLC** of **3 years** it has been shown this would **triple** the output of passenger cars in the **EU**. This would significantly improve both vehicle efficiency and safety. At end of life vehicle (**ELV**) design for disassembly will allow bulk metal components to be reclaimed and sold as preforms for alternative applications. This new business opportunity could provide vehicle manufacturers with **~25** times greater return on the product than is obtained by remelting. Customers could enjoy virtually trouble free motoring and legislators an opportunity to create a fully regulated, controlled and efficient light transport environment which could be adopted by other global regions.

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