Theory of Urban Fabrics: Planning the Walking, Transit and Automobile Cities for Reduced Automobile Dependence

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Abstract

The theory of urban fabrics is outlined showing how different types of cities are combinations of walking, transit and automobile fabrics based on their transport systems and universal travel time budget. The distances/transport speeds that generate these urban fabrics and their associated elements, functions, and qualities are outlined emphasizing for the first time how tasks of statutory planning and transport planning are different in the three urban fabrics. The theory is demonstrated in the Finnish city of Kuopio and with data from the authors' Global Cities Database concluding with three different statutory and strategic planning approaches.

1. Introduction

In this journal in 1955 a classic paper by economist/geographer Colin Clark set out how transport is the 'maker and breaker of cities'. This understanding of how transport shapes cities was given greater scientific credibility by Italian physicist Cesare Marchetti (1994) and Zahavi and Talvitie (1980) who were among the first to show that there is a universal travel time budget of around 1 hour on average per person per day. The travel time budget therefore helps us to see how cities are shaped (Newman and Kenworthy 1999, 2006). The urban fabrics of the cities grow to be 'one hour wide' based on the speed at which people can move in them. If they go beyond this they begin to be dysfunctional and begin to change their infrastructure and land use to adapt again to this fundamental principle (Van Mee and Meurs, 2006, Cervero, 2011).

This paper will show how the three urban fabrics of walking city, transit city and automobile city have formed and now in combination have an on-going life of their own with distinct and important differences in their fabric elements, qualities, lifestyles and economies. Most of all it will show how strategic and statutory planning needs to do more than land use and transport integration, but they need to have different approaches in each of the three urban fabrics.

Most cities in the world today are struggling with the problem of the automobile. Why some cities achieve good results in becoming more transit-oriented and walkable and others less so, is a complex issue involving urban governance, economics, transport planning, town planning and other factors such as vested automobile interests. There continues to be debate about sustainability and the compact city (e.g. Burton, 2003; Naess, 2014) but recent trends suggest demand for automobiles and automobile–based urban fabric is in decline and demand has switched to finding more walking and transit urban fabric (Newman and Kenworthy, 2015). Most planners are therefore faced with the challenge to provide more walkability, better transit systems and denser, mixed uses to create more liveable urban fabric. But do they have a clear framework of concepts, theories and statutory controls which can be used as a tool for achieving these objectives?

Our paper seeks to answer this question and support the existing efforts of planners worldwide to produce cities that are better functioning, more liveable and less dependent on the automobile. It will do this by demonstrating a new theory about the three urban fabrics and how urban planners, citizens, enterpreneurs, politicians, officials and researchers could apply it in their work. The new theory is needed to replace the old but still dominant framework of the Modernist City and its applications which do not distinguish between these different fabrics and which undermine most efforts at rejuvenating walking and transit fabric unless specific intervention is made.

The paper has evolved from recognition of the three basic types of cities and an understanding of how cities work, developed through academic research based on urban data collected from cities around the world and published in books and journals such as Newman and Kenworthy (1989; 1999; 2015), together with the practical work of a city planner working in the small Finnish town of Kuopio for twenty years and published in Kosonen (2007, 2015). The Kuopio work has created the practical application of the theory and tested the concept with results that have been recognised in Finland by Mäntysalo and Kanninen (2013) and extended to other Finnish cities (Ristimaki et al, 2013), though only limited in its further communication. The overlap of interests in how cities work based on their transport systems has led to a parallel way of thinking, parallel concepts and the development of a new theoretical framework we have called three urban fabrics (TUF) which is outlined below.

This paper is the first presentation of the concept, but it is based on many years of work where the concepts have been developed simultaneously by our two groups. It is a theory as it provides explanatory and predictive power for use in any city.

2. History of three urban fabrics

Cities are shaped by many historical and geographical features, but at any stage in a city's history the patterns of land use can be changed by altering transportation priorities. The waves of economic innovation (Hargroves and Smith 2005) led to new traffic and transportation systems and they have been the basis of new comprehensive urban systems building on top of the original walking urban fabric. First the uransit urban fabric and then the auto urban fabric have enabled the growth and vast enlargement of cities. The new fabrics replace some of the old elements, functions and qualities but the three fabrics still exist and are evolving.

Urban fabrics in this theory are products of transport-related lifestyles and functions that have needed certain physical elements and environments to enable them. Each fabric has a particular set of spatial relationships, typology of buildings and specific land use patterns that are based on their transport infrastructure priorities. The original typologies were set out in Figure 1 (Newman and Kenworthy, 1999) and the version used by Kosonen is set out in Figure 2 showing that the three fabrics actually now fully overlap.

The urban fabrics of any city can be identified and the areas of the fabrics can be shown on maps. This kind of documentation and comparison of the maps has shown, that each of the fabrics has an optimal size. These optimal sizes can be marked with dimensional circles and can be understood by the qualities of transport systems in the fabrics that create the daily travel time budgets of the inhabitants (Figure 3). The fabric and the travel times form the basis of much statutory and strategic town planning.

The travel time budget has been found to apply in every city in our Global Cities Data Base (Kenworthy and Laube, 2001) as well as in data on UK cities for the last 600 years (Standing Advisory Committee on Transport 1994). The biological or psychological basis of this seems to be a need for a more reflective or restorative period between home and work, but it cannot go for too long before people become very frustrated due to the need to be more occupied rather than just 'wasting' time between activities. Many functions are carried out in cars as well as transit, biking and walking during travel time that are not considered to be wasted, (e.g. family talk, phone contact, social networking, active exercise), but they are less orientated to the primary functions of work and thus are valued less (Mokhtarian and Chen, 2004).

Debate on the travel time budgets is about how non-work travel time is included as well as how travel time is measured (Mokhtarian and Chen, 2004). However, the way that work place travel time relates to the development of different urban fabric seems to be generally accepted and the data quite powerful.

Understanding this fundamental principle will enable us to see how different urban fabrics have developed, how they can be recognised, respected and regenerated as part of the work of urban planners and designers today and in particular how we can better manage automobiles in future urban development.

This paper will suggest that urban planning has been based on the framework and applications of Modern City concepts with transport planning methodologies acting as though there is only one kind of urban fabric rather than three. It is important to see therefore that there are real differences that have an historical basis, but which can and are being reproduced today by different transport and town planning approaches to the dominant automobile-oriented approaches.

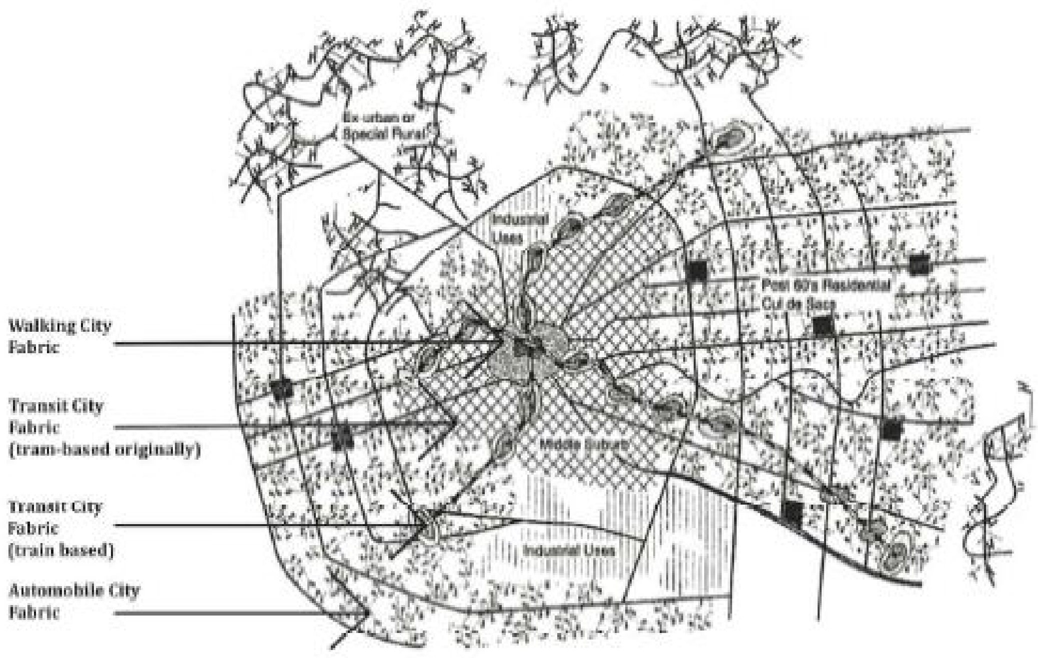

Figure 1. Automobile City, a mixture of three City types
Source: Newman and Kenworthy (1999)

Figure 2. Walking, Transit and Automobile city, a combination of three overlapping city systems
Source: Kosonen (2014)

2.1 The Walking Urban Fabric and Walking Cities

Walking cities have existed for the majority of settlement history since walking was the only form of transport available to enable people to get across their cities at walking speeds of around 3-4 km/h. Thus walking cities were dense (usually over 100 people per ha), mixed-use areas with narrow streets, and were no more than 3 to 4 kilometres across, or roughly 2km in radius. The most intensive part was generally within 1 km radius.

Walking cities were the major urban form for 8,000 years, and substantial parts of cities in Europe and Asia retain these old walking urban fabrics. Cities like Kraców, Barcelona, Ho Chi Minh City, Mumbai, and Hong Kong, for example, retain the character of a walking city. In squatter settlements the urban fabric is usually that of a walking city with dense buildings and narrow, winding streets suitable only for walking. In wealthy cities such as New York, London, Vancouver, and Sydney, the central areas are dominated by walking urban fabric, though they struggle to retain this fabric due to the competing transit city and automobile city fabrics, which now overlap with it.

Many cities worldwide are trying to reclaim the intense urban activity and fine-grained street patterns associated with walkability in their city centres and they find that they cannot do this unless they respect the urban fabric of the walking city areas that still exist today and are generally being recovered, often through pedestrianisation and traffic calming (Gehl, 2010). The building of new walking urban fabric in other parts of polycentric cities is now also firmly on the planning agenda due to its economic attractions (Florida, 2010; Newman and Kenworthy, 2011; 2015).

2.2 The Transit Urban Fabric and Transit Cities

The transit urban fabric since 1850 was based first on trains and then trams. The steam train began to link cities from the 1820's and then began to be the basis of train-based suburbs from the 1850's. This led to early transit cities, which were followed by the later transit cities of trams (from the 1890's) that extended the urban fabric of the old walking cities (Hall, 1992). Both trams and trains could travel faster than walking – trams with average speeds of around 10-20 km/h and trains at around 20 – 40 km/h. This meant cities could now spread out in two ways with trams forming the urban fabric of the inner transit city 10-20 kms across, based very often on a regular grid street structure with trams operating on many of those streets (5-10 km radius with an average around 8 kms) and with trains forming areas of the outer transit urban fabric 20 – 40 kilometers across (10-20 kms radius).

The transit urban fabric that formed around such modes was different based on either trams or trains. Trams created linear development as they were slower and had closer spacing of stops (around 250m was the standard of the time); this led to strips and grids of rather dense, mixed land use transit fabric. Trains created dense nodal centres with mixed land uses along corridors with around one mile station spacing. Thus train-based urban fabric had walking urban fabric at stations like pearls along a string. Densities along the corridors and in the sub-centres could be less than in walking cities (around 50 per ha) as activities and housing could be spread out further. The key characteristic was proximity to this new kind of transport mode, so that urban development became anchored to the tram corridors and the rail-based urban villages. Development only occurred in places where a stop could be reached within a 5 to 10 minute walk.

The central parts of subways in Paris, London and New York are from the 19th century and were essentially designed to extend the walking city, with a network of walking urban fabric areas around the stations. The distance between the stations was, and still is, less than 500 metres and the subways travelled at around 15 km/h and so spread the walking urban fabric, extending in Paris for 5 km, in New York for 4 km and in London about 2 km. Around that area the subways are serving the inner transit fabric, together with trams and buses up to 8 kilometres and some of the lines reach out to serve the areas of the outer transit fabric like trains. The oldest metro systems are speedier today (e.g. the London Metro has an average speed today of 33 km/h, Paris metro 27 km/h and New York 29 km/h (authors' Global Cities update data) and are thus enabling more train-based urban fabric further out as well as the old walking city fabric.

Since 1950 the new areas of the inner transit urban fabric have been based mainly on basic bus lines running from new areas to the centre, such as in Kuopio and other small transit cities of Scandinavia and indeed across Europe. Also, new tram-based neighbourhoods such as Vauban in Freiburg, Germany and Pikku Huopalahti in Helsinki have been constructed during the last decades with increasing commitment to tram city urban renewal, which is now accelerating in many cities (Newman et al, 2013). Most big cities and parts of intermediate size cities have trams or light rail as the basis of their inner transit urban fabric supplemented by buses, especially in those areas where rail has been removed. In addition to rail based transit cities, there is a big number of bus based transit cities and large areas of transit urban fabric that are more or less permanently bus based now.

Transit urban fabric can be found also outside the limits of the inner transit urban fabric (which was shaped mostly by trams). This fabric, which we are calling outer transit urban fabric, is based on trains, fast metro or fast light rail lines supplemented by feeder buses or fast bus lines with limited stops to the centre. These can go out much further than the old tram and Metro networks or basic bus lines and the fabric is based mainly on corridors of stations and dense sub-centres. These are now extending out 20 km or more depending on the speed of the trains (e.g. the Paris RER suburban rail network has an average speed of over 40 km/h, suburban rail in New York averages 50 to 55 km/h and London's suburban rail network averages around 57km/h - from authors' Global Cities update data). Busways and bus-only lanes on freeways and arterials are doing the same in newer areas of the outer transit urban fabric, which don't have a rail system, though their average speeds are generally no more than about 35 km/h, depending on stopping patterns.

Most European and wealthy Asian cities retain this transit urban fabric, as do the old inner cores and corridors in US, Australian, and Canadian cities. Many developing cities in Asia, Africa, and Latin America have the dense corridor form of a transit city, but they do not always have the transit systems to support them, so they often become car and motorcycle saturated (e.g. Bangkok, Hanoi and Jakarta). Singapore, Hong Kong and Tokyo have high densities in centres based on mass public transit linkages and this dominates their transport modal split. Cities such as Shenzhen, Jakarta and Dhaka have grown very quickly, with dense, mixed use transit urban fabric based only on buses and paratransit; the resulting congestion shows that there is a fundamental mismatch between their land use and their transport infrastructure and that their activity intensity demands mass public transit (Dimitriou, 2013). Most of these emerging cities are now building the public transit systems that suit their urban form. For example, Bangkok now has a considerable network of elevated metro and Shenzhen opened a metro system in 2004. China is building 86 metro rail systems and India is building 56 metros to support their transit urban fabric (Newman et al, 2013).

The 'peak car,' phenomenon (Millard-Ball and Schipper, 2010; Gargett, 2012; Newman and Kenworthy, 2011) appears to be related to a simultaneous rediscovery of the value of walking and transit city fabrics, especially a new awareness of their economic value (Glaeser, 2011; Newman and Kenworthy, 2015). There is also an increasing number of cities building fast urban rail due to its travel time savings over deteriorating automobile traffic congestion (McIntosh et al 2013; Newman and Kenworthy, 2015).

2.3 The Auto Urban Fabric and Automobile Cities

Automobile-based urban fabric took over much of the old walking and transit fabric once roads and parking for automobiles was provided. Trams of the transit urban fabric were frequently replaced by buses and buses were used as a supplementary service to the car, thus leading to increased loss of the transit urban fabric though the fundamental building structure and layout remained and is now having a resurgence.

As urban development was no longer anchored to fixed-track systems, it could be extended to wherever roads could be built. Hence the opportunity to continue creating transit city corridors was replaced by large continuous suburbs first in cities of the USA, Australia and Canada and later in many kinds of cities around the world. Buses became merely supplementary to cars in the new automobile-based urban fabric. Cities which became automobile cities thus provided limited public transit to support their sprawling suburbs, mostly through infrequent and slow regular bus services without bus lanes, Within a generation such areas became the basis of automobile dependence (Newman and Kenworthy, 1989) and automobility (Urry, 2004).

Automobile Cities from the 1950s onward could spread beyond the 20 km radius to some 80 km diameter (up to 40 kilometres radius) in all directions, and at low density because automobiles could average 50-80 km/h while traffic levels remained low. The period of large-scale freeway construction in the 1960s and 1970s attempted to enable automobile access e.g. the Interstate Highway system in the USA saw massive freeway construction across all American cities (Schiller et al, 2010). Cities with such infrastructure could then spread out in every direction due to the flexibility of cars. Single-use zoning that separated activities and increased trip lengths then became feasible within the travel time budget. Densities reduced in such fabric to less than 20 people per ha.

Cities in the new world in the past 70 years have grown mostly with automobile dependent suburbs. Many European and Asian cities are now building such suburbs around their old transit urban fabric, though significantly less than in the new world cities and generally not quite as low density. In Asian cities the use of the private car is often supplemented by large numbers of motorbikes that seem to thrive in the denser transit urban fabric due to shorter travel distances, greater manoeuvrability in congested, tight areas and easier parking.

Peri-urban areas exist around most cities and are usually highly car and truck dependent (a lot of industry has scattered outside the main urban fabric), even though the peri-urban area may have originally been based on rural village economies and practices (Piorr et al, 2011). These areas are considered therefore to be a part of the automobile urban fabric in most of their structural features.

The promise of speed and flexibility through automobile-based urban development has rapidly evaporated due to the growth in traffic congestion. Cars are twenty- times more spatially inefficient than urban rail in terms of passenger flows per lane and thus across the world's growing cities there are significant speed gains by rail compared to road traffic. From the authors' Global Cities Database the ratio of overall public transport speed to traffic speed increased from 0.55 to 0.70 between 1960 and 2005, while the ratio of urban rail system speed to general traffic speed went from 0.88 to 1.13, i.e. rail is now on average significantly faster than general traffic (Newman and Kenworthy, 2015). Australian, European and Asian cities are a lot higher in this ratio with Asian cities at 1.52. This phenomenon is likely to change forever the dynamic that has led to the universal growth in automobile urban fabric.

So what can we see emerging next?

As demonstrated by the new evidence of 'peak car' (see below) there is a simultaneous movement to demand more walking urban fabric and transit urban fabric so that people can walk and use transit within the universal travel time budget, and at the same time to build fast urban rail that can enable the automobile urban fabric that is stuck in its traffic to link to the rest of the city.

Automobile cities are now looking to extend fast mass transit to their car dependent suburbs (Newman et al, 2013). Congested traffic now means that average automobile travel is less than 35 km/h and thus many people in outer suburbs are trapped in travel time budgets beyond their desirable limit. New fast trains (averaging over 80 km/h) can extend the transit city out beyond the previous maximum distances and well beyond the 20 km radius of the transit city (see the case study on Perth in McIntosh et al, 2013 where new urban rail lines extend 40 to 70 km from the city centre). These fast trains are thus changing the nature of automobile dependence by providing an option that the automobile cannot provide.

In the same way that automobile-based urban fabric overlaps with walking and transit urban fabrics, these new rail lines are bringing transit fabric into automobile cities. At first the new transit lines tend to attract automobile fabric such as park and ride lots, but after a few years the willingness to pay for reduced travel time leads to increased density of activity around transit stops. This is happening at stations on Perth's fast train lines deep within automobile city fabric, as well as in places like Tysons Corner in Washington DC (Lukez, 2007). Cities are thus finding new ways to combine their three urban fabrics.

3. Combinations and overlaps of three urban fabrics.

Figure 2 shows the overlap of the three transport-related urban fabrics. The transit urban fabric overlaps and covers parts of the area of the walking urban fabric. It brings residents of the transit fabric to the services and other functions of the centre and the walking urban fabric, but can have negative impacts on its inherent capacity to assist pedestrians and cyclists. The automobile urban fabric, which overlaps and covers all the walking urban fabric and all the transit urban fabric, in many cases can obliterate them (e.g. in US cities such as Detroit). In numerous cases it has been so dominating it has destroyed the underlying transit and walking urban fabrics. It can, however, also work in symbiosis with the transit and walking urban fabrics, e.g. visitors from the automobile urban fabric often come by car to these other fabrics and if parking and other automobile city elements are not unduly disturbing the transit and walking qualities of these areas, then the extra people add to the value of the walking or transit urban fabric and functions. The CBD of all cities has usually become a combination of walking, transit and automobile urban fabric elements as it tries to attract all kinds of economic and social activity to its focus.

Other modes such as cycling, motorcycles and para-transit (e.g. auto-rickshaws, jitneys, tuk-tuks), can also fit the theory, though they have not been included as major modal transport-related urban fabric generators, as in general they fit into the three other fabric types. For example, it might be argued that motorcycles so utterly dominate the transport of Ho Chi Minh City, that it could be called a "motorcycle city", though in fact Kenworthy and Laube (2001) show that the city is so dense at 356 persons per ha, that walking and cycling account for nearly 50% of all trips.

The outer part of the walking city was supplemented by trams and today by buses and by cycling. Cities with heavy usage of bicycles such as Amsterdam or Copenhagen generally have strong walking urban fabric that is extended out into the areas formerly created as transit fabric by trams and now accessible through cycling. Those cities, which have maintained effective tram systems or promoted cycling, now have areas, which are mixtures of walking and transit urban fabrics. These areas can extend the walking urban fabric up to 5 km in radius but no further.

Figure 3 shows some conceptual combinations of the three urban fabrics. The figure is a theoretical conception of a metropolitan area with a strong transit urban fabric. The concept indicates the areas of the urban fabrics which are explained in the paper. The dimensional circles indicate the optimal sizes of different types of areas of these urban fabrics.

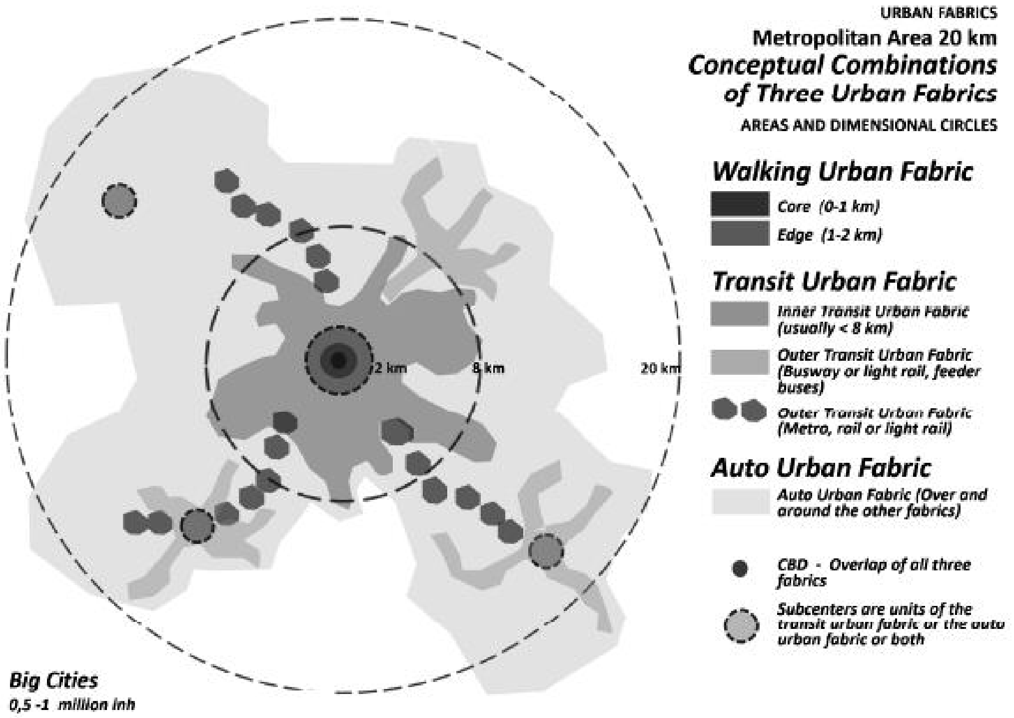

Figure 3. Conceptual combinations of three urban fabrics
Source: Kosonen (2014)

The theory of urban fabrics suggests that all cities can be described by a combination of these three urban fabrics. This paper will provide a semi-quantitative basis for showing how these urban fabrics combine in different types of cities and how these cities and their fabrics can be understood in terms of their spatial dimensions through several case studies. The theory and its associated framework is explanatory and predictive, but it also will always depend on the peculiarities of geography, history, culture and politics to fully explain or predict the combinations of the three fabrics, but that is normal in town planning.

4. Maps and concepts of the city types

In Figure 4 below we show example maps of three city types as applications of the conceptual combinations of the urban fabrics. From the maps it is possible to see that the general patterns of the three transport-related urban fabrics are evident. However, the same way as there are different urban forms of cities, there can be variations of concepts of urban fabrics due to combinations of city size, geography, culture and politics.

City size generally indicates the age of the city and the potential for a longer period of growth in the walking city and transit city eras. It also means that this fabric can be built upon to create extensions of the walking city and transit urban fabrics.

We have suggested three examples of how the size of the city may impact on the variations and overlaps in the three urban fabrics (Figure 4). The same patterns and spatial dimensions outlined above hold true.

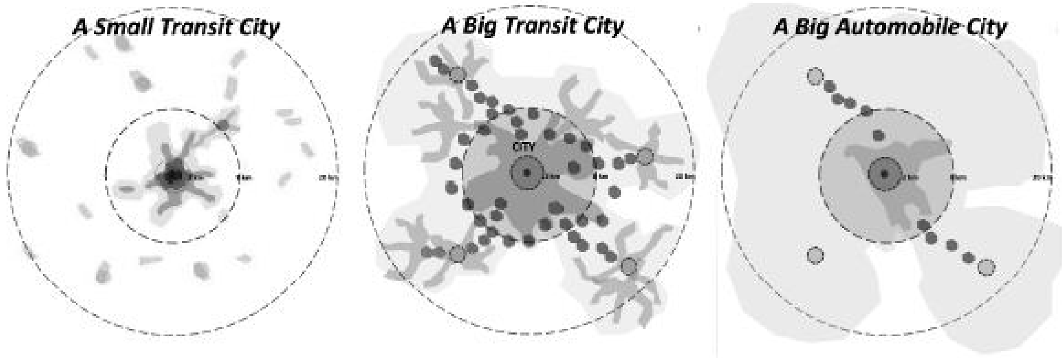

Figure 4. Three examples of city types - small transit city, big transit city, big automobile city
Source: Kosonen (2014)

Geography sets the amount of land available to build on; some cities have a lot of water in their surroundings or steep land that cannot be built on. By reducing the amount of land in the central area the proportion of walking city especially can be significantly reduced (e.g. Hong Kong). Transit cities can face the same situation (e.g. Barcelona) but once they consist of corridors, they can more easily fit into constrained geographies.

Culture and politics determine the extent to which each urban fabric is preferred for residential and commercial activity. In the US, Canadian and Australian cities the high proportion of automobile urban fabric indicates their 20th century history of removing tram systems (apart from Melbourne) and building fast, car-based infrastructure and other automobile urban fabric in all parts of the city (Newman and Kenworthy, 2006). The more dense transit cities of Europe and Asia can also be seen in terms of their culture and politics related to land use planning and transport infrastructure priorities. There appears now to be a global trend toward greater demand for walking and transit urban fabric that has its origins in economics, culture and politics (Puentes and Tomer; 2009; Newman and Kenworthy, 2015).

Having described the three transport-related urban fabrics as having some basis in history and in present cities, the next section sets out some of the quantitative basis for the three urban fabrics and how they combine into three city types. This enables the theory to be understood in terms of the potential interventions and planning processes that can help provide better planning options.

5. The quantitative basis of urban fabrics and three city types

When a city is dominated by one or other urban fabric they can be seen as Walking Cities, Transit Cities and Automobile Cities, though they will always have some part of each fabric evident. The Global Cities Database (Kenworthy and Laube 2001; Kenworthy et al 1999) provides quantitative perspectives on the three types of cities and how different urban fabrics are underpinned by different transport systems. The three urban fabrics can be recognized in any city from maps and aerial photos. Kosonen (2015) has assessed the various quantities of population living in each of the three fabrics for Boston, Melbourne, Munich and Singapore from 1960 using the Global Cities Database (Kenworthy et al, 1999) – see Figure 5.

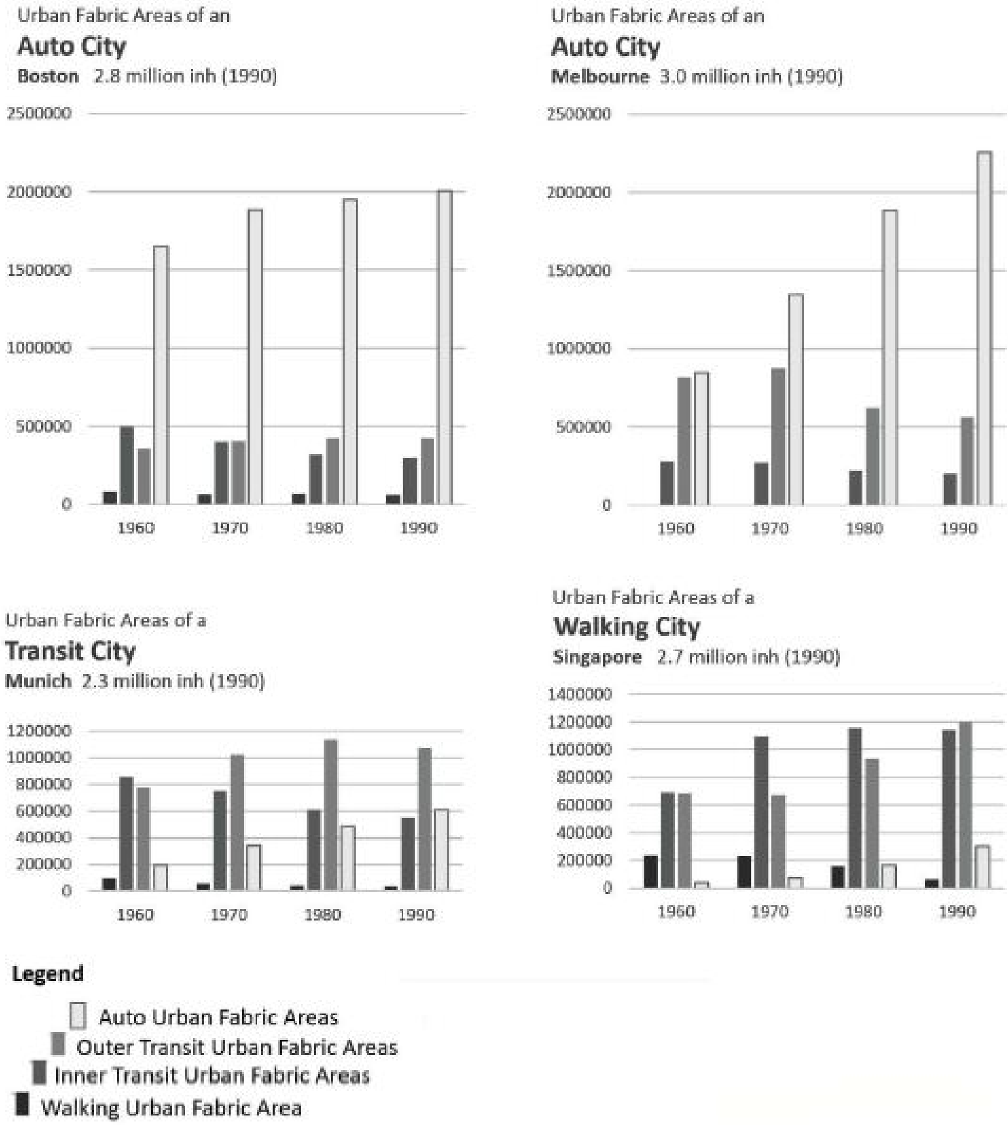

Figure 5. Population living in the different types of urban fabrics from 1960-1990, using automobile city examples from the USA, and Australia, a transit city of Europe and a walking city from Asia
Source: Kosonen (2014)

A more global sample of the variations can be gained by looking at the total mobility per capita in a range of cities by simply using private passenger transport energy per person. As automobiles use two to three times more fuel than transit per pass-km, and automobile urban fabric has much longer kilometres of travel, then it is relatively easy to see how the three city types separate out by looking at this transport fuel use.

Figure 6 shows the huge range in per capita energy use for private passenger transport that characterizes cities across the world. They all have a combination of these three urban fabrics - walking, transit and automobile urban fabrics– and the combinations with more walking and transit fabric are likely to have considerably less transport energy per person.

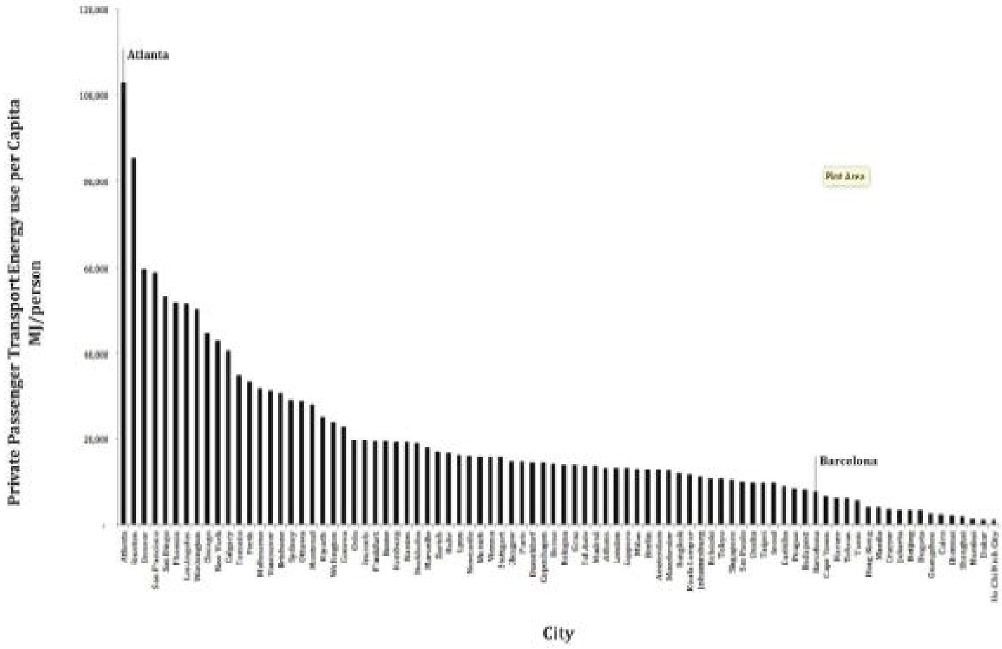

Figure 6. Private passenger transport energy use per person and urban density (persons per ha) 1995
Source: Kenworthy and Laube (2001)

The differences between the cities are dramatically shown by comparing Barcelona which uses just 8 GJ per person per year compared to 103 GJ in Atlanta, a difference of thirteen times and yet the GDP per capita in Atlanta was only 1.7 times more than

Barcelona in 1995. The difference seems to be that Barcelona is substantially a walking city with some strong elements of the transit urban fabric and almost no trace of any auto urban fabric, whereas Atlanta is almost completely an automobile city with just a little of the transit and walking urban fabrics.

The transport-related urban fabric picture is expressed in Figure 7 where travel patterns are exponentially related to urban population density. Atlanta is six persons per ha and Barcelona is 200 per ha. From the two inflexion points in Figure 7 we suggest that less than 35 people per ha is the cut-off below which cities become predominantly automobile cities; the 100 people per ha represents the point above which cities are predominantly walking cities; and transit cities are predominantly between 35 and 100 people per ha.

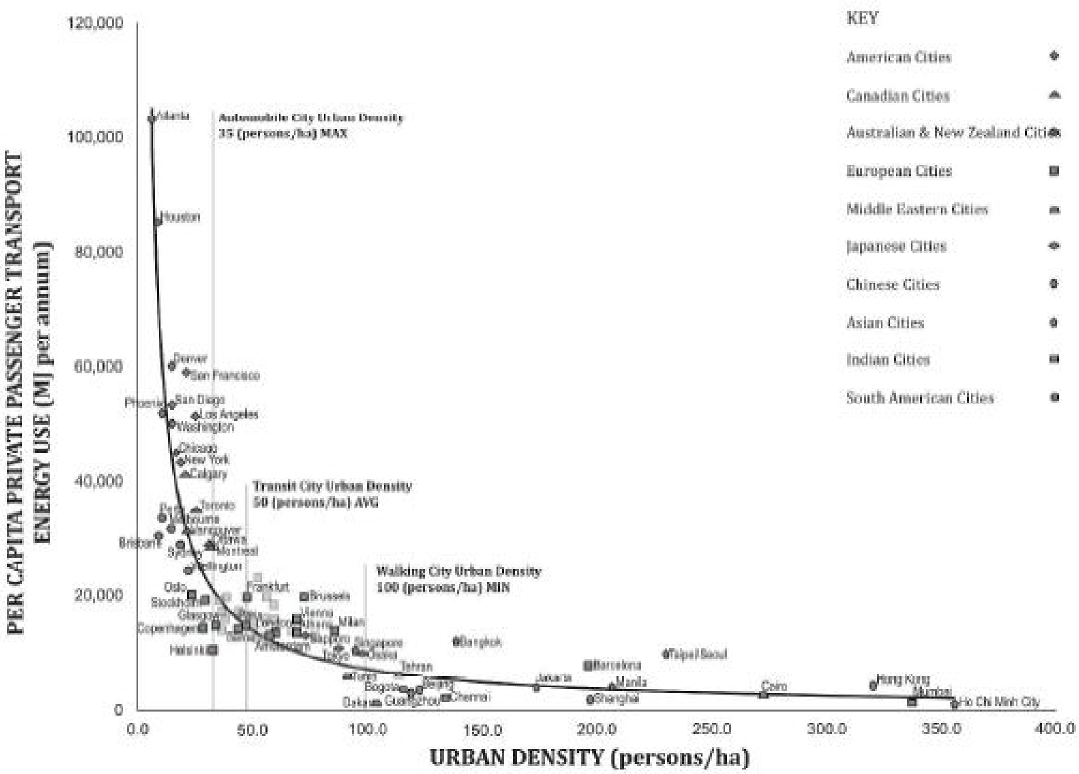

Figure 7. Private passenger transport energy use per person in cities across the world, with links to different urban fabrics 1995
Source: Kenworthy and Laube (2001)

The same patterns can be seen within cities where the centres are mostly areas of walking urban fabric, the inner to middle suburbs are mostly areas of transit urban fabric and the outer suburbs consist mostly of areas of automobile urban fabric. Where data for Melbourne and Sydney are combined covering transport greenhouse gases per person by suburb versus the number of residents and jobs per ha (activity density) in each suburb, a very similar curve to Figure 7 is obtained with a very strong statistical fit (Trubka, Newman and Bilsborough 2010). The same inflexion points of around 35 per ha and 100 per ha are evident (Figure 8).

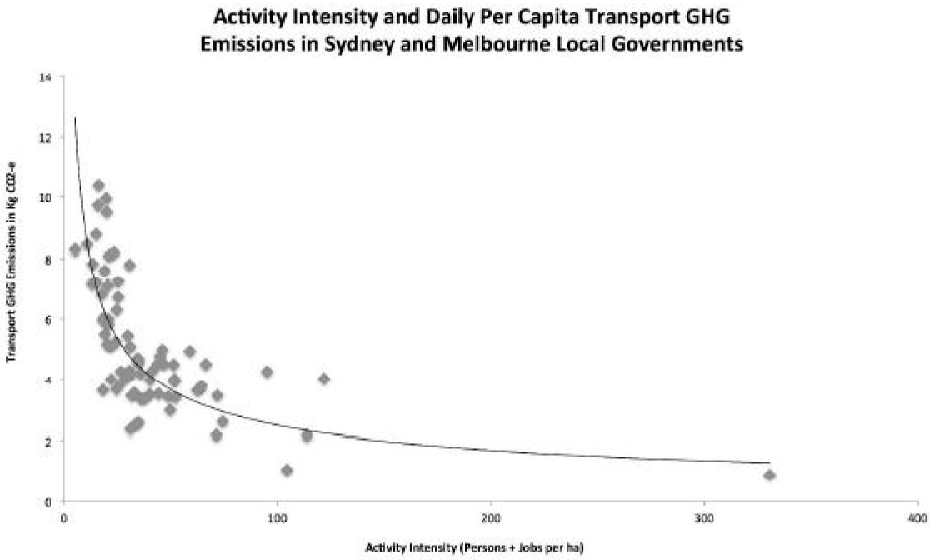

Figure 8. Transport greenhouse gases per person versus activity density for suburbs of Melbourne and Sydney
Source: (Trubka, Newman and Bilsborough, 2010)

Questions of wealth do not appear to be driving this phenomenon, as there is for instance in Australian cities, an inverse relationship between urban intensity and household income – outer suburbs are poorer and yet households in these areas can drive from 3 to 10 times as much as households in the city centre. As the data for Melbourne in Table 1 indicate, the poorer households are driving more, using transit less and walking less because of where they live.

	Core Area	Inner Area	Middle Suburbs	Fringe Suburbs
Percentage of Households earning >$70,000/year	12%	11%	10%	6%
Car Use (trips/day/person)	2.12	2.52	2.86	3.92
Public Transit (trips/day/person)	0.66	0.46	0.29	0.21
Walk/Bike (trips/day/person)	2.62	1.61	1.08	0.81

Table 1. Differences in wealth and travel patterns from the urban core to the urban fringe in Melbourne
Source: Newman and Kenworthy (2001, 62).

There are obviously complex interactions that influence the intensity of activity and how this impacts on transport patterns (Copola etal, 2014; Ewing and Cervero, 2010; Bertolini and Dijst, 2003). Many discussions have tried to explain transport patterns in non-land use terms (Brindle 1994; Mindali, Raveh and Saloman 2004), but the data and analysis above suggest that the physical fabrics of a city do have a fundamental impact on movement patterns and vice versa. This paper will now try to take the next step and explain how the theory of urban fabrics can help to further understand the important role of planning in establishing and managing these fabrics through outlining the town planning features of the fabrics.

6. Town Planning features of the urban fabrics: areas, elements, functions and qualities

Approaches to town planning since the 1930's have oriented towards various types of "Future Cities", disregarding the previous forms of urban fabric. The Athens conference of CIAM in the 1930's led by Le Corbusier produced the concept of The Functional City with living, working and recreation as the main functions and categories of land use and transport as a function that combines the land use types. This set the scene for post-war automobile-based planning with suburbs placed where only automobiles and secondary buses could service them (Mumford, 1961). The orientation led to practices, conventions and governance which regard the city as one single functional unit with land use and traffic as its main categories of city planning. Our theory of three urban fabrics shows that, instead of one single urban fabric with land use and transportation as its main categories, cities should be identified as a combination of three overlapping fabrics. Each of the fabrics have their own types of land use and transport systems. Once these systems are recognized as distinct urban fabrics, then the potential is there for each to be optimized by integrated combinations of transport and land use planning. In addition to that, the identification of the three urban fabrics is a good basis for various types of sectoral plans and programmes like the plans of service networks and local services, housing policies, recreation policies, business programmes, planning of healthy urban environments, architectural policy and indeed any area of town planning (Kosonen 2015)

Findings by fabrics can easily be combined to achieve comprehensive conclusions concerning the city as a whole or left for each fabric in a local area. This is a good basis to handle and supervise the dynamic and dialectic processes of the city and its planning through strategic and statutory planning.

In Tables 2 to 5 we have set out a selection of the basic features of the transport-related urban fabrics. The contents of these tables are based on observations concerning the fabrics, which can be easily distinguished such as the walking urban fabric of good city centres like Amsterdam, transit urban fabric of good districts like Vauban (Freiburg im Breisgau) and auto urban fabric of automobile cities like Perth. The main source of observations has been the daily practical experience of the City of Kuopio over the past 20 years as it applied the theory in its planning needs and has been added to through the global experiences of the other authors. The tables show:

- Fabric areas (spatial dimensions, areas, sub-areas and overlaps for each urban fabric);
- Fabric elements (physical components which are the working buildings and infrastructure that enable each urban fabric to function in its own way);
- Fabric functions (the habits, ways of life and business functions of the users and providers in each fabric);
- Fabric qualities (the measurable outcomes in terms of urban form, transport, economic, social and environmental qualities in each urban fabric).

The documentation to justify the simple characteristics for each feature is substantial with attempts at detailed data in Newman and Kenworthy (1989, 1999, 2015). The goal here is to provide an overview and hopefully many cities will use the framework to fill out the actual data for their city. These can then be collected and processed during the next stagesof compilation of the theory.

		Walking Urban Fabric	**Transit Urban Fabric**	**Automobile Urban Fabric**
Urban Fabrics and the Fabric Areas	*1) Optimal Dimensional Radius of the Fabric*	**0-2 km** *-Area where the elements and functions of the walking urban fabric can be found*	**0-20 km** *-Area where the elements and functions of the transit urban fabric can be found*	**0-40 km** *-Area where the elements and functions of the automobile urban fabric can be found*
	2) Areas of the Fabrics	Areas which are dominated by the elements and functions of the walking urban fabric	Areas which are dominated by the elements and functions of the transit urban fabric	Urban areas outside the areas of the walking and transit urban fabrics
	3) Overlaps of other fabrics	Area of the walking urban fabric include elements and functions of the other fabrics. It usually hosts the CBD, which is usually a combination of all three urban fabrics	Areas of the transit urban fabric may have also elements and functions of the automobile fabric (which usually deteriorate the transit fabric) The sub-centres have elements and functions of the walking urban fabric	Areas of the automobile urban fabric may have elements and functions of the transit urban fabric (which make it more versatile) Areas with no overlaps are car dependent
	4) Sub-divisions of the Fabric Areas and their Optimal Dimensions	The core of the walking urban fabric 0-1 km The outer areas of the walking urban fabric 1-2 km	The inner areas of the Transit urban fabric 1-8 km The outer areas of the transit urban fabric 8-20 km	The areas of the automobile urban fabric are around the areas of the other fabrics, up to 40 km

Table 2. Fabric Areas
Source: Own Data (Peter Newman and Leo Kosonen)

		Walking Urban Fabric	Transit Urban Fabric	Automobile Urban Fabric
Urban Fabrics and the Fabric Areas	*1) Optimal Dimensional Radius of the Fabric*	**0-2 km** *-Area where the elements and functions of the walking urban fabric can be found*	**0-20 km** *-Area where the elements and functions of the transit urban fabric can be found*	**0-40 km** *-Area where the elements and functions of the automobile urban fabric can be found*
	2) Areas of the Fabrics	Areas which are dominated by the elements and functions of the walking urban fabric	Areas which are dominated by the elements and functions of the transit urban fabric	Urban areas outside the areas of the walking and transit urban fabrics
	3) Overlaps of other fabrics	Area of the walking urban fabric include elements and functions of the other fabrics. It usually hosts the CBD, which is usually a combination of all three urban fabrics	Areas of the transit urban fabric may have also elements and functions of the automobile fabric (which usually deteriorate the transit fabric) The sub-centres have elements and functions of the walking urban fabric	Areas of the automobile urban fabric may have elements and functions of the transit urban fabric (which make it more versatile) Areas with no overlaps are car dependent
	4) Sub-divisions of the Fabric Areas and their Optimal Dimensions	The core of the walking urban fabric 0-1 km The outer areas of the walking urban fabric 1-2 km	The inner areas of the Transit urban fabric 1-8 km The outer areas of the transit urban fabric 8-20 km	The areas of the automobile urban fabric are around the areas of the other fabrics, up to 40 km

Table 2. Fabric Areas
Source: Own Data (Peter Newman and Leo Kosonen)

		Walking Urban Fabric	Transit Urban Fabric	Automobile Urban Fabric
Fabric Elements	*1) Street Widths*	Narrow	Wide enough for transit	Wide enough for cars/trucks
	2) Squares & Public Spaces	Frequent as very little private open space	Less frequent as more private open space	Infrequent as much greater private open space
	3) Street Furniture	High level for pedestrian activity	High level for transit activity (bus stops, shelters)	High level for car activity (signs, traffic lights)
	4) Street Networks	Permeable for easy access; enables good level of service for pedestrians	Permeable for pedestrians, networks to reach transit stops, corridors enable good levels of transit service	Permeability less important, enables high levels of service for cars on freeways, arterials and local roads. Bus circulation often restricted by cul-de-sac road structure.
	5) Block Scale	Short blocks	Medium blocks	Large blocks
	6) Building Typologies	High density minimum 100/ha usually	Medium density minimum 35/ha usually	Low density <35/ha, often much less than 20/ha.
	7) Building Set Backs	Zero set backs	Setbacks minimal, for transit noise protection and more space	Setbacks large for car noise protection and extra space
	8) Building Parking	Minimal for cars, seats for pedestrians, bike racks	Minimal for cars, seats for pedestrians, often good bicycle parking	Full parking in each building type
	9) Level of Service for Transport Mode	Pedestrian services allow large flows of pedestrians	Transit services allow large flows of transit users	Car capacity allows large flows of cars

Table 3. Fabric elements
Source: Own Data (Peter Newman and Leo Kosonen)

		Walking Urban Fabric	**Transit Urban Fabric**	**Automobile Urban Fabric**
Fabric Functions and Lifestyles	*1) Movement/Access* *-Functions*	High by Walking Medium by Transit Low by Car	High by Transit Medium by Walking Medium by Car	High by Car Low by Transit Low by Walking
	2) Consumer Services *-Shopping* *-Personal Services*	High local - especially niche services	High in corridors -especially sub centres	High, - especially shopping centres, but dispersed
	3) Large-Scale Consumer Services *-Hypermarkets* *-Warehouse Sales* *-Car Yards*	Low	Medium	High
	4) Industry Functions	Small -More white Collar	Medium -More labour intensive e.g. hospitals, education	Large -More blue collar
	5) Face-to-Face Functions *-Financial & Admin* *-Creative Decision-Making* *(aka Richard Florida)* *-Knowledge Exchange* *-The Arts*	High	Medium	Low
	6) Car-less Functions	High	Medium	Low
	7) Lifestyles *-Walking City Lifestyle* *-Transit City Lifestyle* *-Automobile City Lifestyle*	Major Possible Possible	Possible Major Possible	Not Possible Difficult Major

Table 4. Fabric functions and life styles
Source: Own Data (Peter Newman and Leo Kosonen)

		Walking Urban Fabric	Transit Urban Fabric	Automobile Urban Fabric
Fabric Qualities	*1) Urban Form Qualities* *-Density* *-Mix*	High High	Medium Medium	Low Low
	2) Transport Qualities *-Car Ownership* *-Level of Service (L.O.S.)* *-Transport Activity*	Low High L.O.S. Ped High Ped Activity	Medium High L.O.S Transit High Transit Activity	High High L.O.S. Car High Car Activity
	3) Economic Qualities *-Development Infrastructure Costs per Capita* *-GDP per Capita* *-Labour Intensity*	Low-Medium High High	Medium-Low Medium Medium	High Low Low
	4) Social Qualities *-Difference between rich/poor* *-Ability to help Car-less* *-Health due to Walking* *-Social Capital* *-Safety*	Low High High High Variable	Medium Medium Medium Medium Variable	High Low Low Low Variable
	5) Environmental Qualities *-GHG per Capita* *-Oil per Capita* *-Footprint per Capita*	Low Low Low	Medium Medium Medium	High High High

Table 5. Fabric qualities
Source: Own Data (Peter Newman and Leo Kosonen)

Tables 2 to 5 show a significant and important set of differences between these three kinds of transport-related urban fabrics. Table 5, showing the variety of different qualities characteristic of the three urban fabrics, indicates why planning is increasingly aiming to rebuild more walking and transit fabric and minimise the extension of automobile urban fabric (Sassen, 1994; Newman, 1995; Dodson and Sipe, 2008; Newman et al, 2009). This theory of three urban fabrics is at odds with the modernist based theories and concepts of cities that have been almost universally applied in urban development for most of the latter half of the 20th century (see Newman, 2015).

7. Implications for Town Planning from the Theory of Urban Fabrics

Town planning has strategic and statutory tools and these can be applied to the three urban fabrics and used to reduce automobile dependence in a number of ways. The most significant strategic approach needed to reduce automobile dependence is to revise the transport modelling that assumes there is only one kind of transport-related urban fabric – which in practice means the automobile-based urban fabric. The standard Four Step Transport Model needs to be revised to facilitate all three transport-related urban fabrics (Newman and Kenworthy, 2015). Strategic town planning needs to reassert the value of the three fabrics and not allow traditional transport planning to set the agenda for cities through its solely automobile-oriented priorities.

Statutory town planning (in all its sectors) needs to recognise, respect and rejuvenate the three fabrics with detailed regulatory requirements as set out in Table 6 for the three fabrics.

Walking Fabric	Transit Fabric	Automobile Fabric
Provide walking infrastructure which can cope with pedestrian flows that are the highest priority of the transport system in the area; Don't widen streets, or insist on set backs; Respect the squares, parks and other public spaces of the area and find out their value and potentials; Ensure sufficient walking space and traffic signals have large times for pedestrian flows; Enable laneways to be connected and active; Apply housing policies and planning that maintain a good level of housing with high density and mixed use; Keep parking to an absolute minimum and preferably underground; Remove automobile city functions that are harmful to walking and cycling such as through traffic and fast traffic of one-way streets with green light waves and street-based parking in narrow streets; Remove automobile city elements such as sections of freeway that are harmful to pedestrians or renew them to fit the walking urban fabric.	Provide quality transit as the major transport system in each corridor of transit –related development; Ensure corridors are well serviced with transit otherwise the lifeblood of the fabric will shift to automobiles; Apply housing policies and planning that maintain a good level of housing conditions with at least medium density; Maintain and create good qualities of the street scale environment to enable local service units to stay and service the local residents within proper walking distances; Remove automobile elements that are harmful or renew them to fit the transit urban fabric, eg maintain roads wide enough for buses and trams, but not high capacity car use; Provide as far as is feasible, reserved rights-of-way for transit operations to ensure on-time running and speed-competitiveness with cars; Optimise transit infrastructure to ensure a high quality of service (e.g. passenger information systems, shelters, system maps); Build up corridors and centres along historic and new tram and train lines; Keep parking to a minimum through maximum allowable parking instead of minimum parking requirements.	Separate functions into clear residential, industrial, retail and other uses, but where it is reasonable, mix the functions which need to be mixed; Provide large set backs on buildings that need vehicle space but avoid inefficiency where feasible; Don't increase densities and mixed use without subsequent transit systems to support such densification; Provide high capacity roads where needed especially for freight but not for people-orientated economic activity; Provide sufficient car parking but avoid the large asphalt expanses associated with 20th century shopping malls and office parks.

Table 6. Statutory Guidelines to Reduce Automobile Dependence in Three Urban Fabrics
Source: Authors

In Kuoppio the recognition of the three fabrics (Figure 9) led to the delivery over 20 years of three different sets of approaches to strategic and statutory planning.

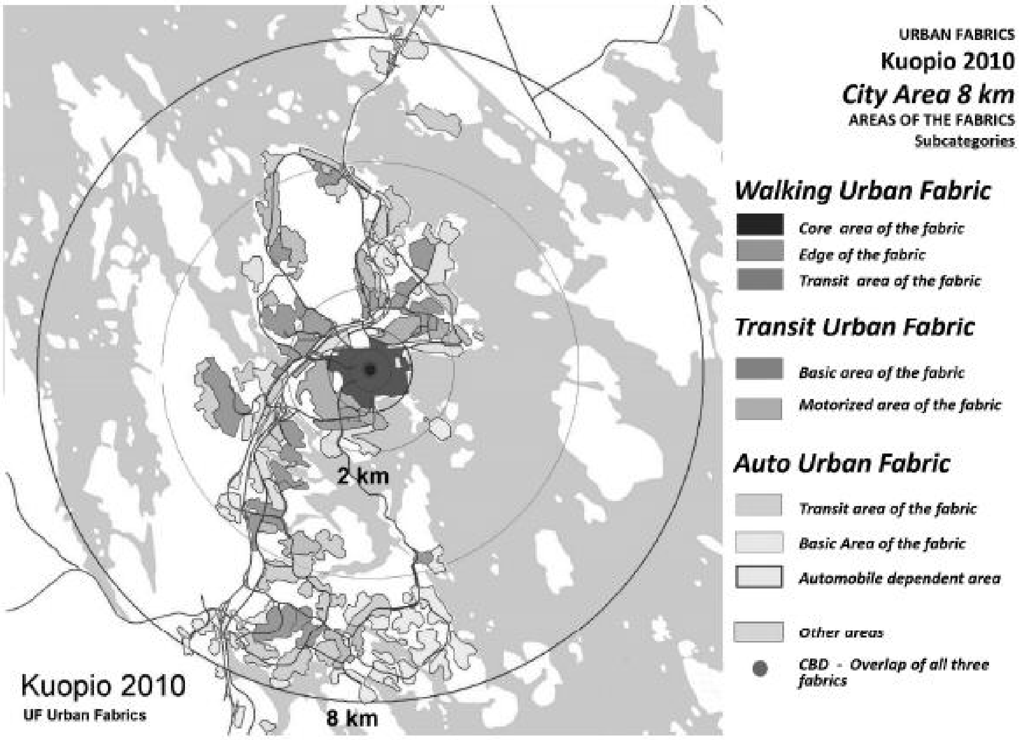

Figure 9. Three Urban Fabrics in Kuopio, 2010
Source: Kosonen (2007; 2015)

Walking fabric in Kuopio was first recognised and respected in the 1994 Plan when urban laneways in the city centre were defined and a restoration process began that continues today. There are now ten kilometres of walking city laneways that have been restored for that purpose in this small city.

Melbourne, New York, Copenhagen and many other large cities have similarly instituted a plan that respects their walking urban fabric with spectacular results in terms of increased pedestrian activity and walking city functions, as well as demand for more walking urban fabric (Gehl, 2010). The elements, functions and qualities of the walking city are now demonstrated as having obvious economic, environmental and social value by economists and social scientists like Leinberger (2014) who found that the top six most walkable cities in America have 38% higher GDP than the rest of American cities, and Florida (2012) and Glaeser (2010) who have found that high density, high amenity, walking scale environments are better able to attract knowledge economy jobs because they offer the kind of environmental quality, liveability and diversity that these professionals are seeking.

Transit fabric in Kuopio was first recognised in 1993 when the planners saw that a number of neighbourhoods were going to have their level of bus services reduced unless a series of other neighbourhoods could be renewed, extended and linked together in a string of pearls corridor. This eventually led to a bus and cycle/pedestrian-only bridge that was completed in 2001; the new bus urban fabric has led to rapidly increasing transit patronage along that corridor.

Transit city regeneration and extension into car-based suburbs is now on the agenda in many cities instead of continuing car-based urban sprawl. Old transit corridors and middle suburbs are now the focus of greater density and better transit (Newton et al 2013; Glackin et al 2013). Many new urbanist developments that promise less car use in these areas are primarily emphasizing changes to improve the legibility and permeability of street networks, with less attention to the urban fabric such as density of activity and transit linkages (Falconer and Newman 2010; Falconer et al, 2010). As important as such changes are to the physical layout of streets, we should not be surprised when the resulting centres are not able to attract viable shopping or commercial arrangements and have only weak public transit. The fabric of the area needs to become more transit–related or it will continue to be automobile dominated.

The elements, functions and qualities of the automobile city dominate most town planning schemes and a range of functions will need to be respected for what they are: they were built around the automobile and the truck and little else will be possible without them and the spatial patterns that support them.

The main agenda for the future of cities today is dominated by the concept of the polycentric city (Bertolini and Clercq, 2003). It is seen as the most significant contribution of town planning to such global issues as climate change (IPCC, 2014) and multiple local issues of sustainability (Bertolini and Dijst, 2003; Davoudi, 2003; King, 2004; Coppola et al, 2014; Curtis, 2008; Naess, 2014). To implement a polycentric city requires awareness of the theory of urban fabrics. The concept requires more transit corridors and walking centres right across the city and deep into automobile city fabric. The first signs of how this can work have been demonstrated with fast urban rail and redeveloped shopping centres and edge cities (McIntosh et al, 2013,14; Lukez, 2007).

8. Conclusions

The theory of urban fabrics has enabled us to understand the dynamics of city changes over the past and into the present based on their transport priorities and the spatial outcomes that this entails based on the universal travel time budget. The three urban fabrics are quite distinct in their elements, functions and qualities though town planning has generally not recognized their differences, generally preferring the Modernist approach of one functional city with the one set of manuals to plan and manage them. This has been a major contributor to the growth of automobile dependence in both the creation of new auto fabric on the urban fringe and the deterioration of walking and transit fabric due to the imposition of automobile fabric such as parking, road widening and large setbacks.

The greater value of walking and transit urban fabric is now appearing as the phenomenon of peak car use suggests that the age of automobile dependent urban planning dominance is over and the need to extend this into car-based suburbs has become a high priority in town planning. Rejuvenating old and building new, attractive walking and transit urban fabric across the city will require creativity by town planners and transport planners who will need different strategic and statutory manuals for built form typologies that fit the different urban fabrics. Without this the dominant automobile city framework will still be used despite the economic, environmental and social demand for more walking and transit fabric.

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